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# **INDOOR ENVIRONMENT AND ENERGY CONSUMPTION OF URBAN RESIDENTIAL BUILDING IN CHINA**

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# CONTENTS

- 1. Introduction**
- 2. Overview of CO<sub>2</sub> emission & energy consumption in the world**
- 3. Energy use in China**
- 4. Space heating & cooling and indoor temp.**
- 5. Investigation of energy use**
- 6. Calculation of HVAC loads and energy saving**
- 7. Conclusion remarks**

# INTRODUCTION - Background

- Energy consumption is increasing rapidly due to the growth of economy in China.
- For the sustainable development, it is necessary to make a program of energy conservation strategies in conjunction with realization of healthy and comfort indoor environment.
- However, there is little information of indoor environment for examining the effect of energy conservation strategies.

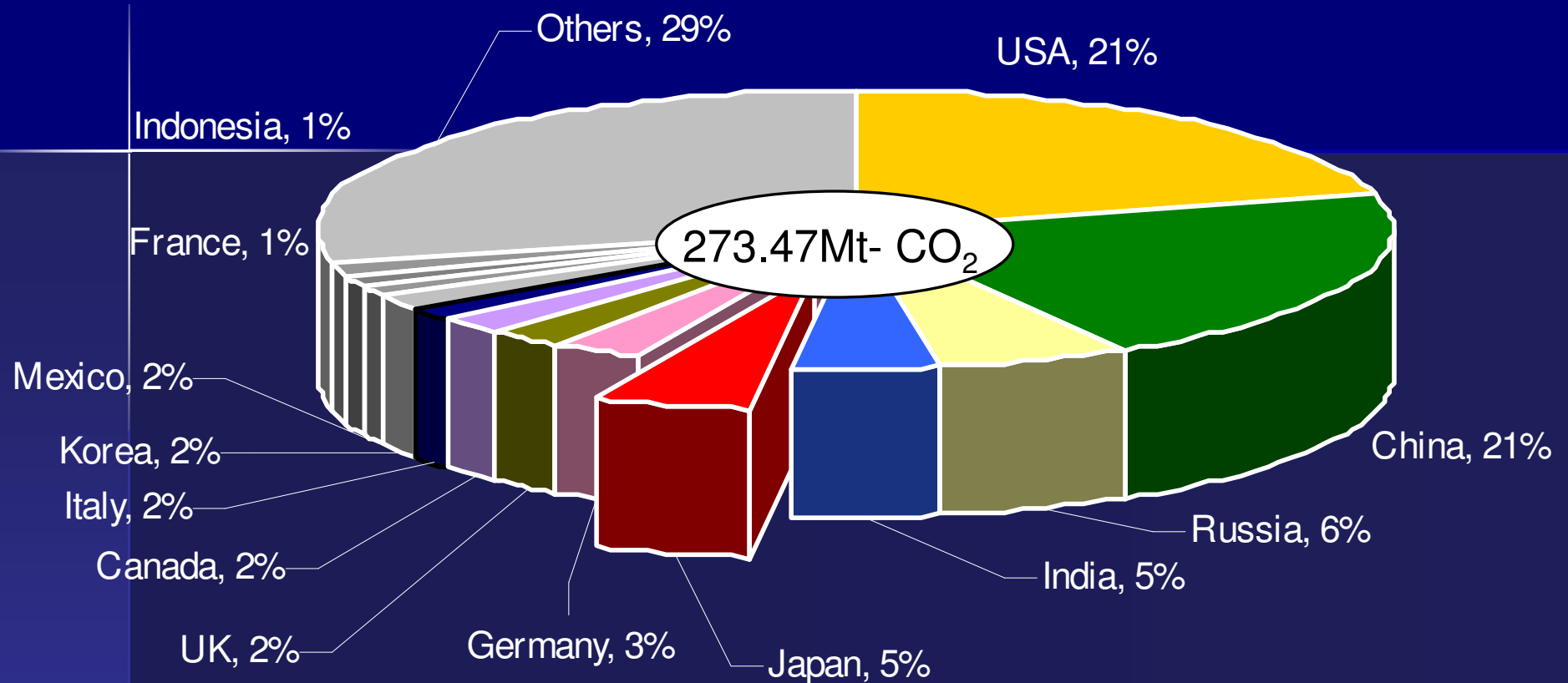
# INTRODUCTION – Purposes of this study

- To make clear the actual conditions of the indoor thermal environment and energy consumption of urban residential buildings in main cities of China.
- To estimate the possibility of energy saving by thermal insulation, air-tightness, and other strategies.

# CONTENTS

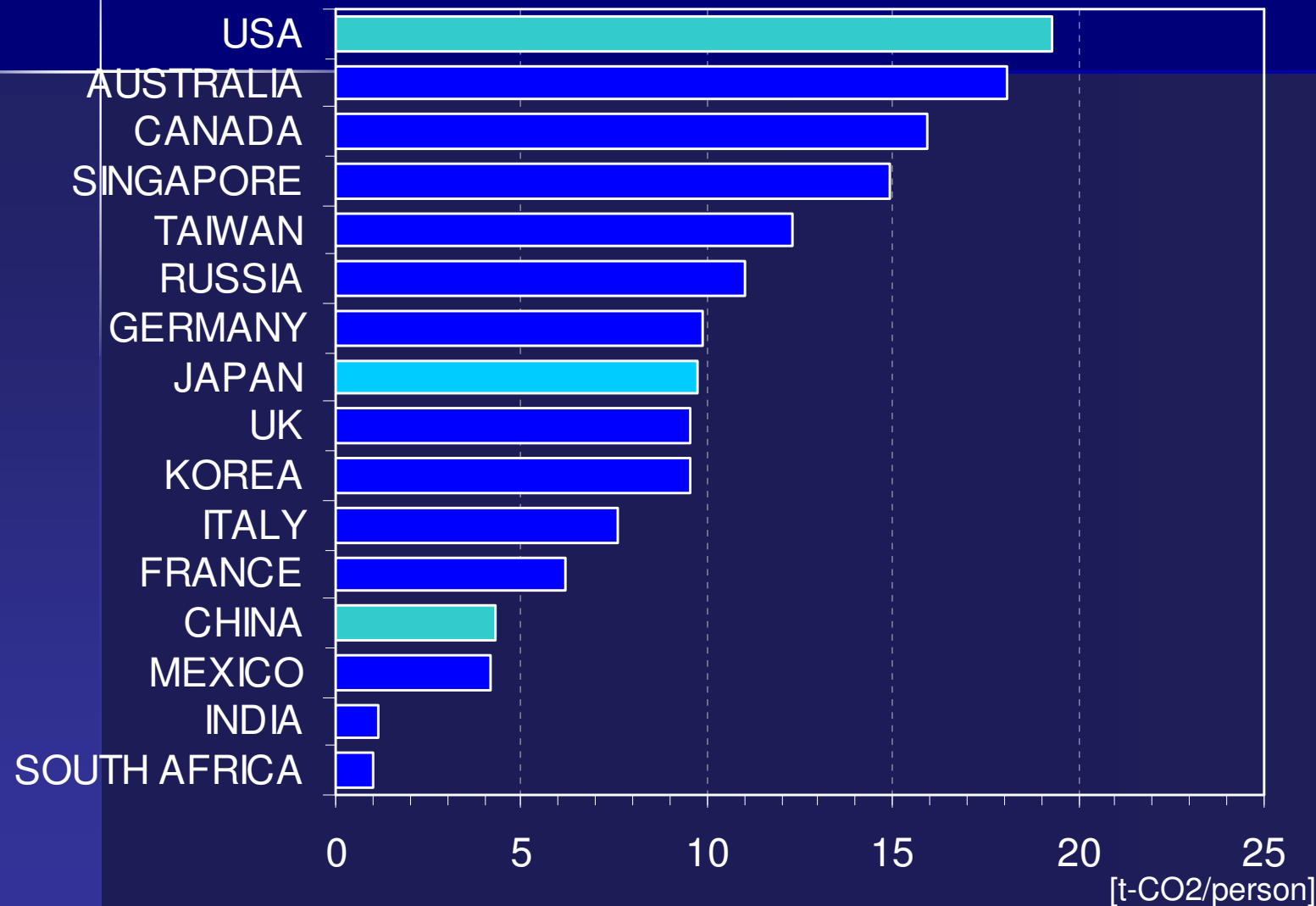
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2. Overview of CO<sub>2</sub> emission & energy consumption in the world
3. Energy use in China
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5. Investigation of energy use
6. Calculation of HVAC loads and energy saving
7. Conclusion remarks

# CO<sub>2</sub> emission in the world (2005year)



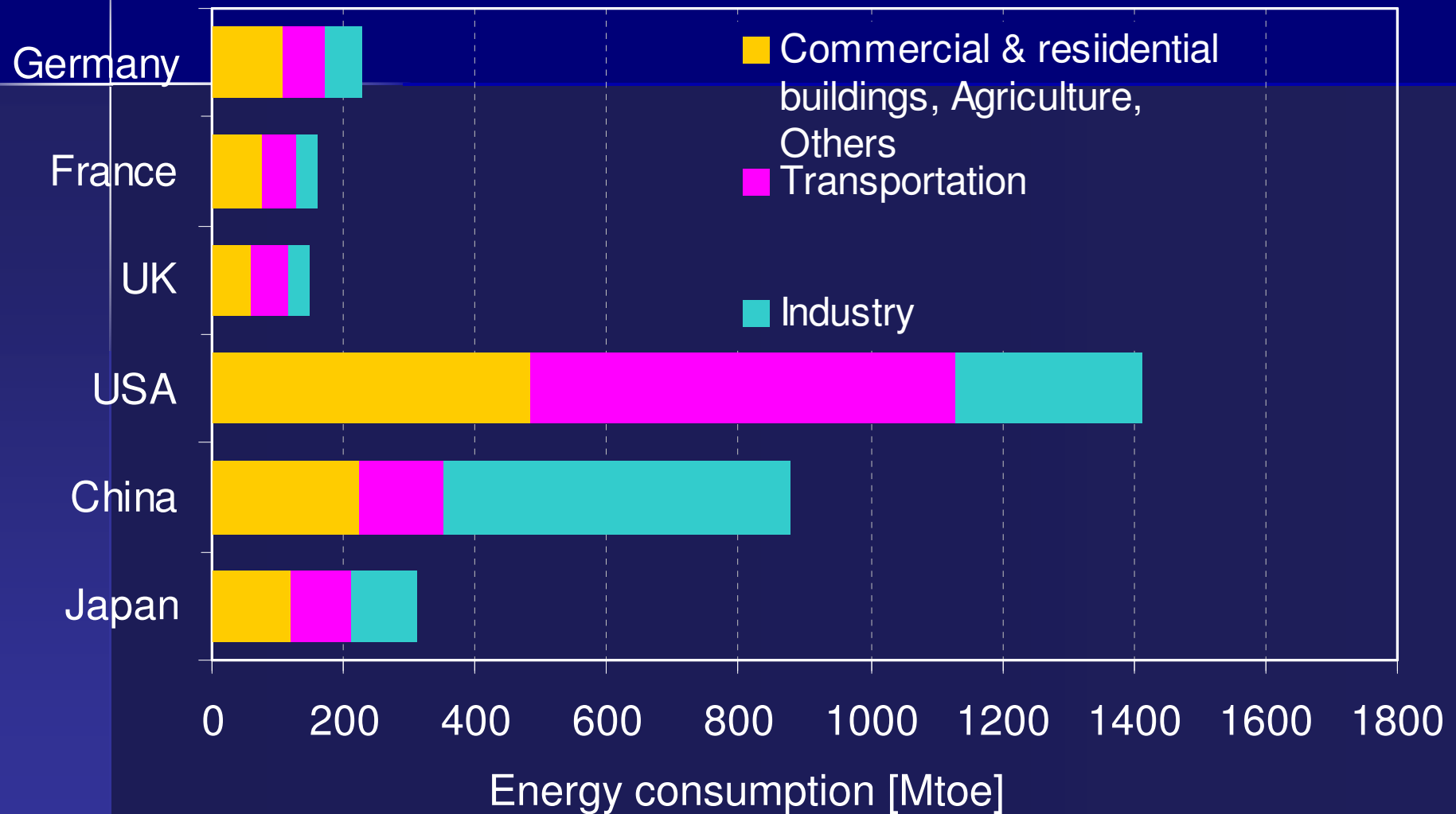
- The Four countries constitute half of the world's CO<sub>2</sub> emission. China and Japan are the 2<sup>nd</sup> and 5<sup>th</sup> highest CO<sub>2</sub> emissions country.

# International comparison of CO<sub>2</sub> emission per person in 2005 year



(Handbook of energy & economic statistics in Japan, 2009 , The Institute in Energy Economics, Japan) 7

# Annual energy consumption for end use

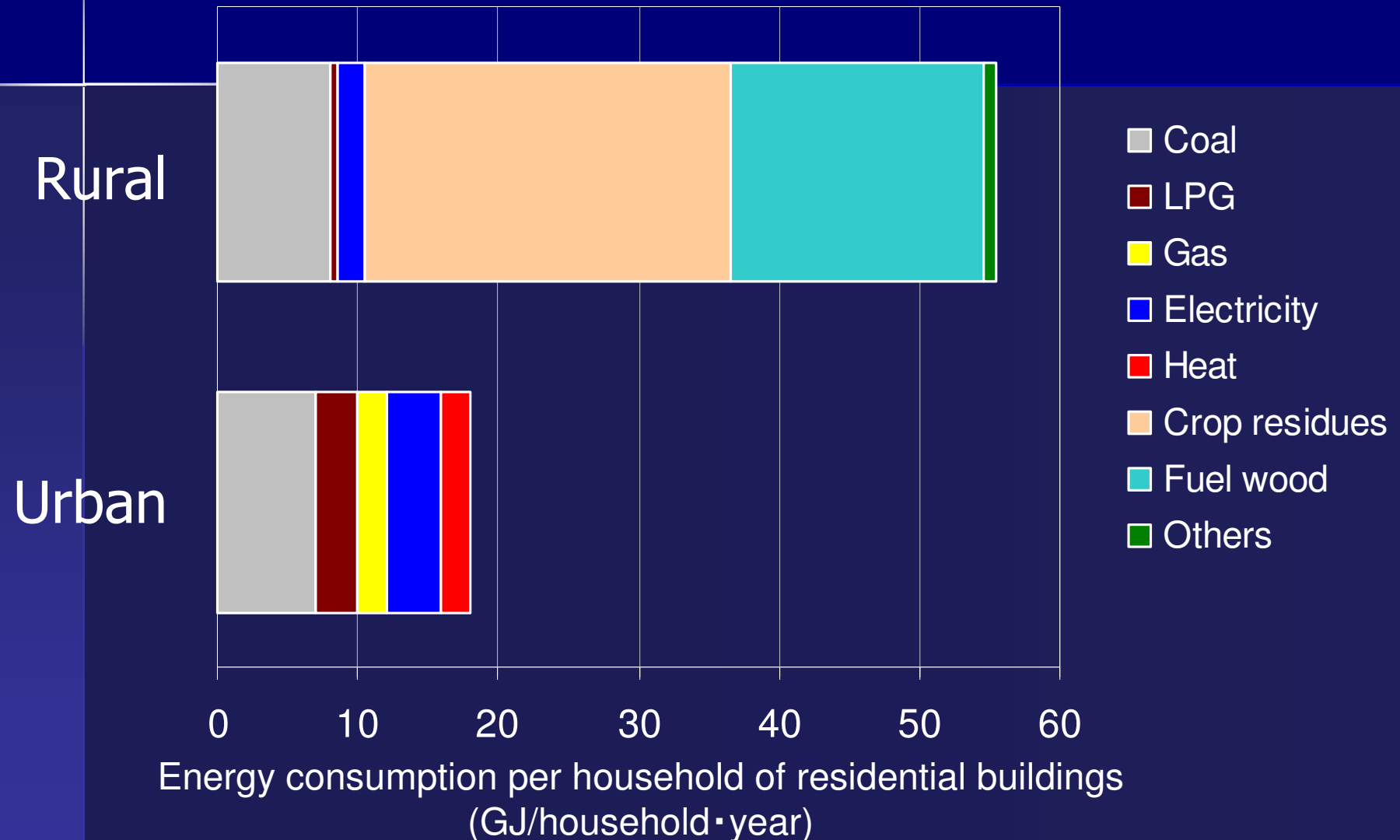


(Handbook of energy & economic statistics in Japan, 2009 , The Institute in Energy Economics, Japan)

# CONTENTS

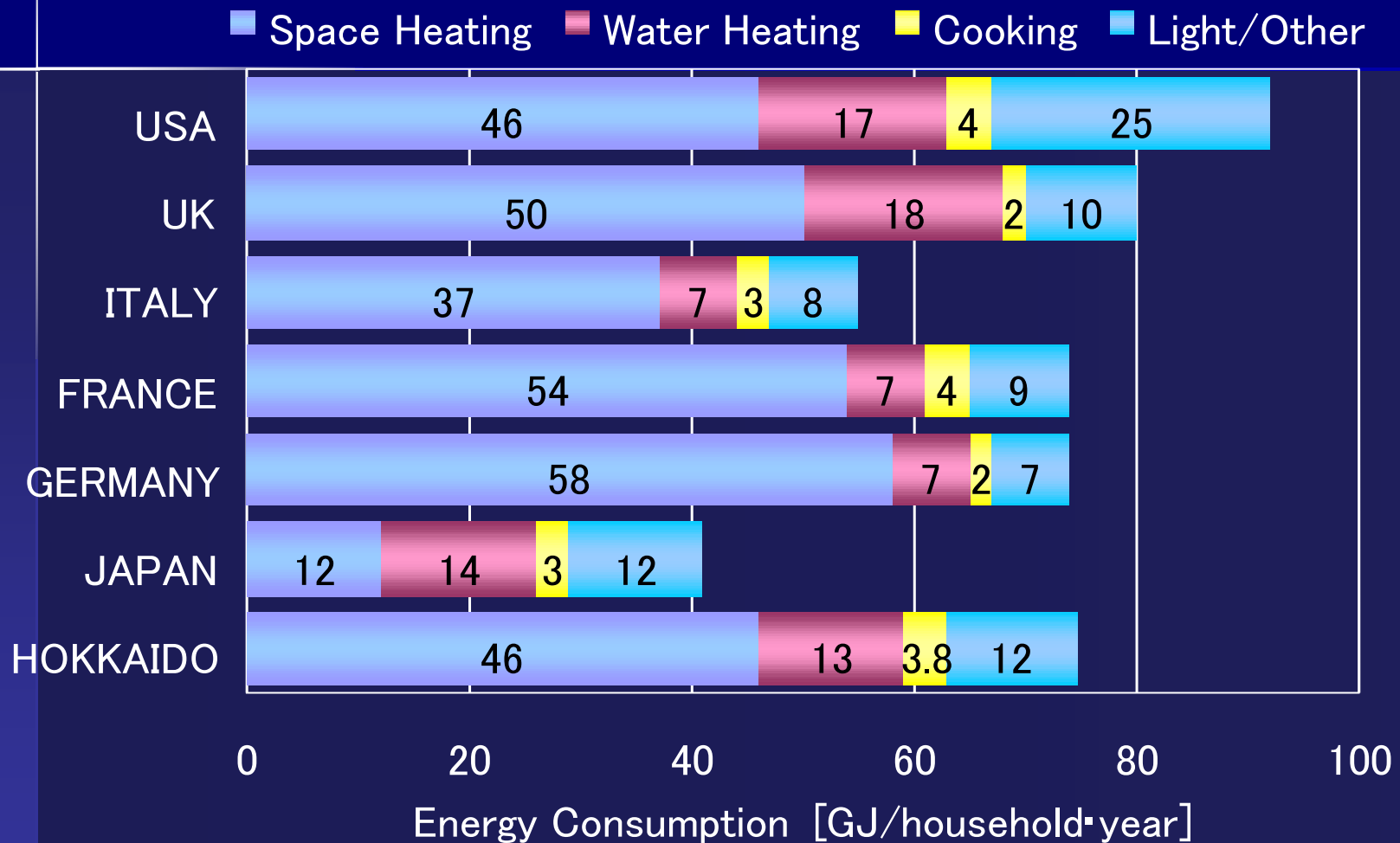
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2. Overview of CO<sub>2</sub> emission & energy consumption in the world
3. Energy use in China
4. Space heating & cooling and indoor temp.
5. Investigation of energy use
6. Calculation of HVAC loads and energy saving
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# Residential energy use per capita in urban and rural area (2003)



(H.Nakagami; Study on Residential Energy Consumption in Asian Countries, AIJ2008)

# Residential energy comparison in main countries



# CONTENTS

1. Introduction
2. Overview of CO<sub>2</sub> emission & energy consumption in the world
3. Energy use in China
4. Space heating & cooling and indoor temp.
5. Investigation of energy use
6. Calculation of HVAC loads and energy saving
7. Conclusion remarks

# Location of the cities investigated

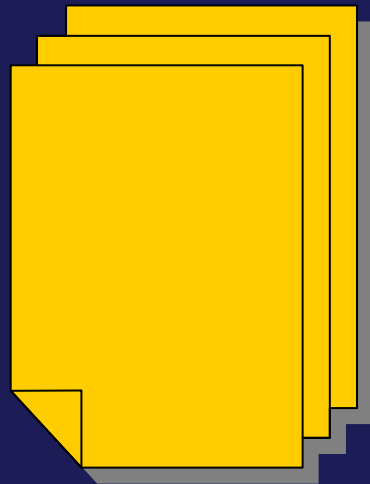
GB 50176-93 Standard of climate regionalization for architecture



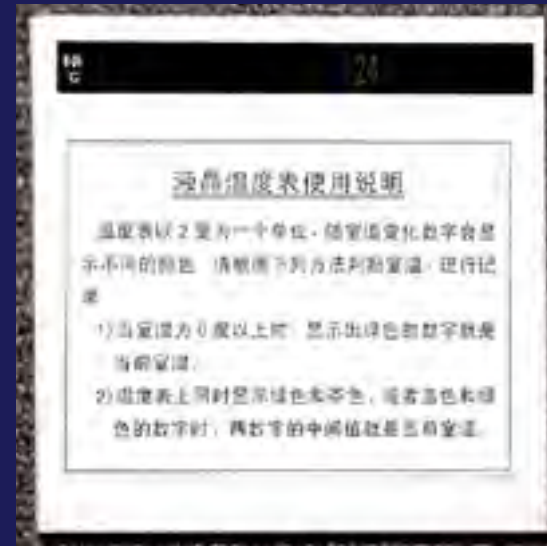
# Methods for investigation

## 1) Questionnaire approach

Questionnaire and liquid crystal thermometer were distributed to 36 - 120 families in each city.



**Questionnaire**



**Liquid crystal thermometer**

# 1) Questionnaire approach

## Distribution of the questionnaires

Questionnaire and liquid crystal thermometer were distributed to the families arranged by the local researchers.

Harbin, Urumqi, Xi'an, Changsha, Chongqing, Kunming  University

Beijing  High school (Winter)  
University (Summer)

Shanghai  Primary and high school (Winter)  
University (Summer)

Hong Kong  University and high school

# 1) Questionnaire approach

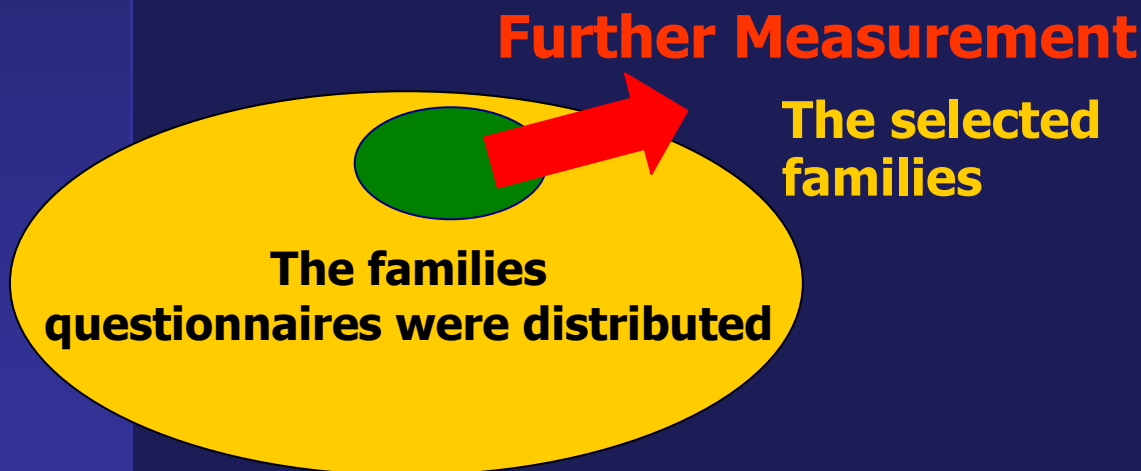
## Contents of the questionnaire

Building characteristics	Construction year, Structure, Floor areas, Windows, Condition of balcony
Housing equipments	Heating & cooling system, Ventilation system, Equipment of hot-water supply
Residential characteristics	Number of occupants, Income
Life styles	Heating & cooling period, Heating & cooling time, Garment insulation value
Satisfaction ratings	satisfaction of thermal comfort and residential environment
Energy consumption	Monthly consumptions of gas and electricity
Indoor thermal environment	Temperature in the morning, daytime and evening

# Methods for investigation

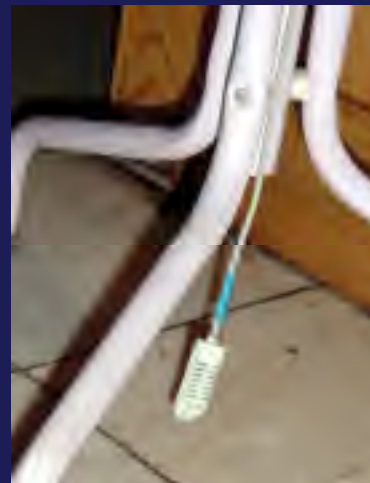
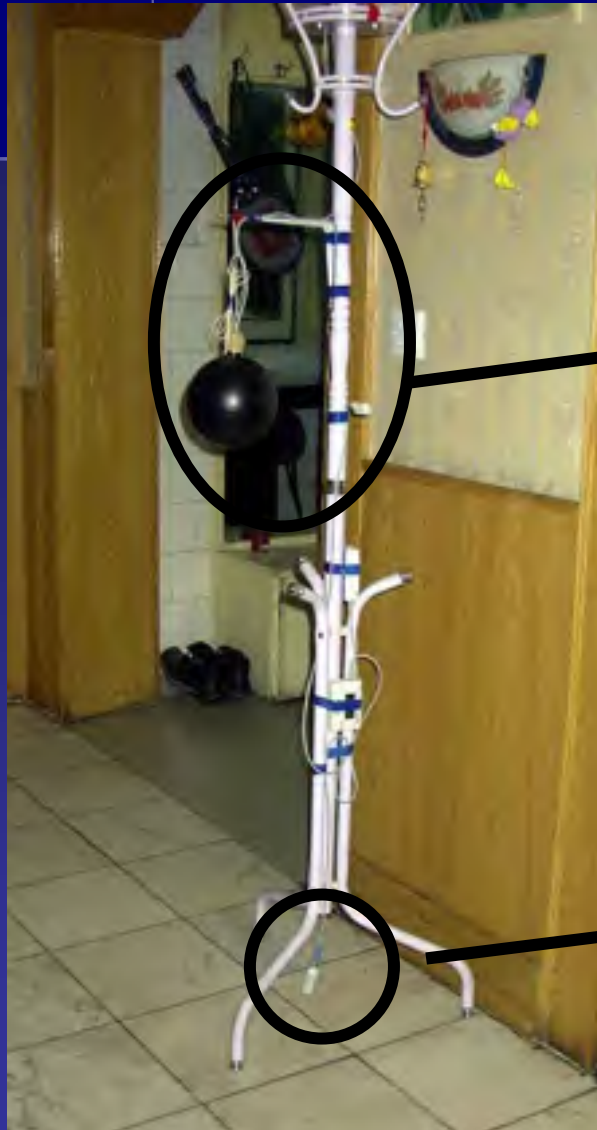
## 2) Field Measurement approach

Indoor temperature and humidity were measured by small data loggers with sensors, which were set up in living room and bedroom for a week in 3 - 12 families in each city.

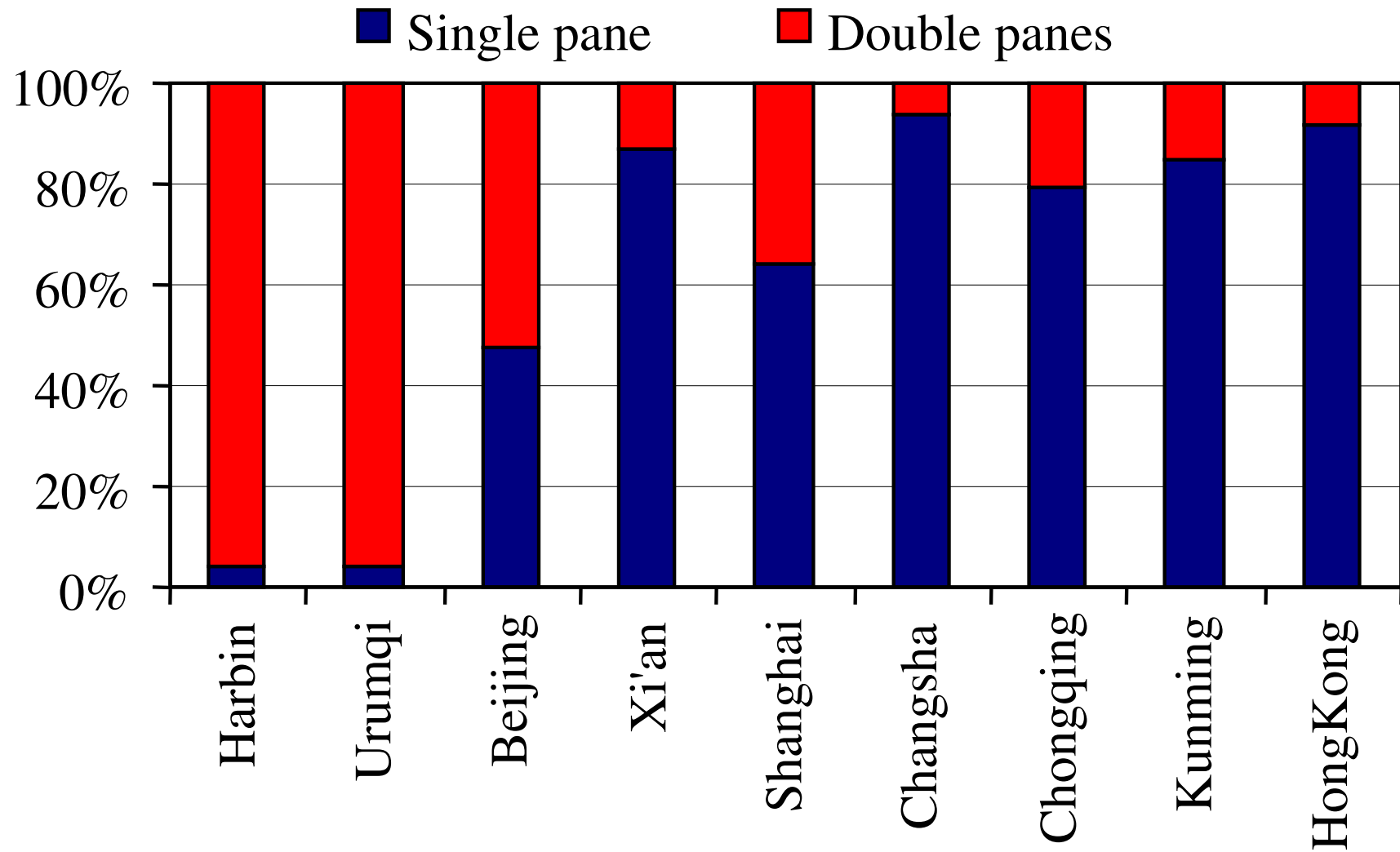


**Small data logger with sensor**

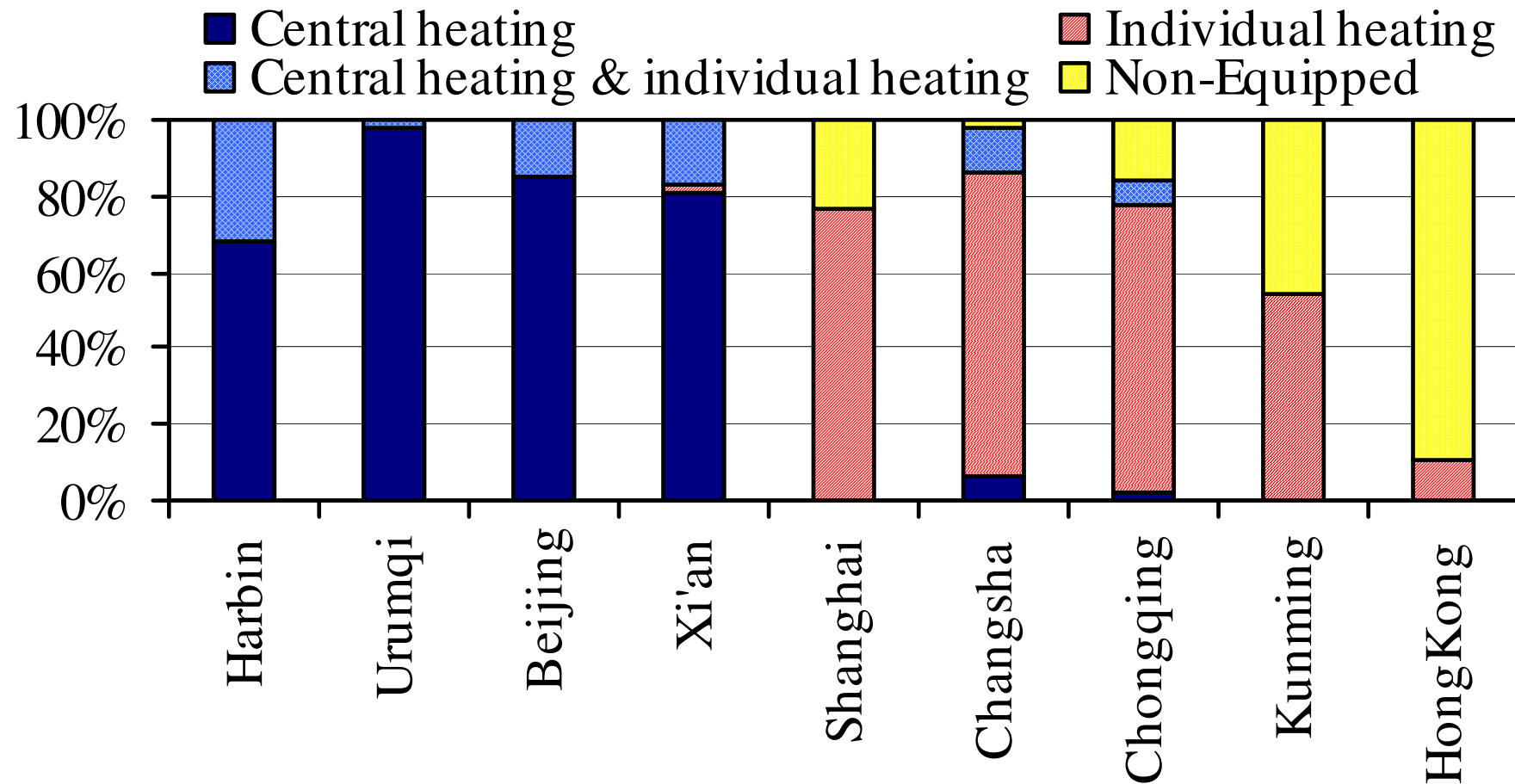
# Indoor measurement settings



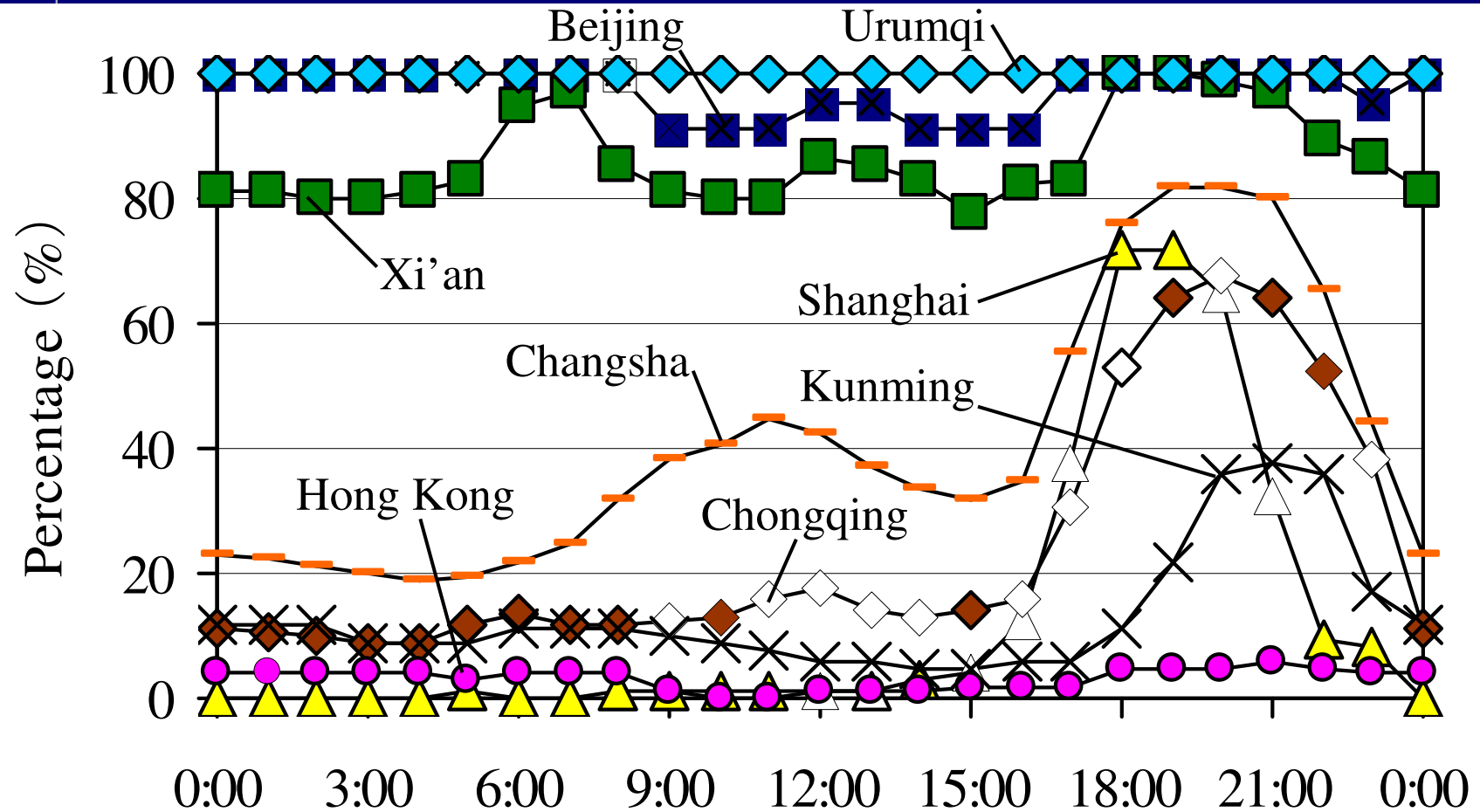
# Type of window



# Ratio of apartments with space heating system or apparatus

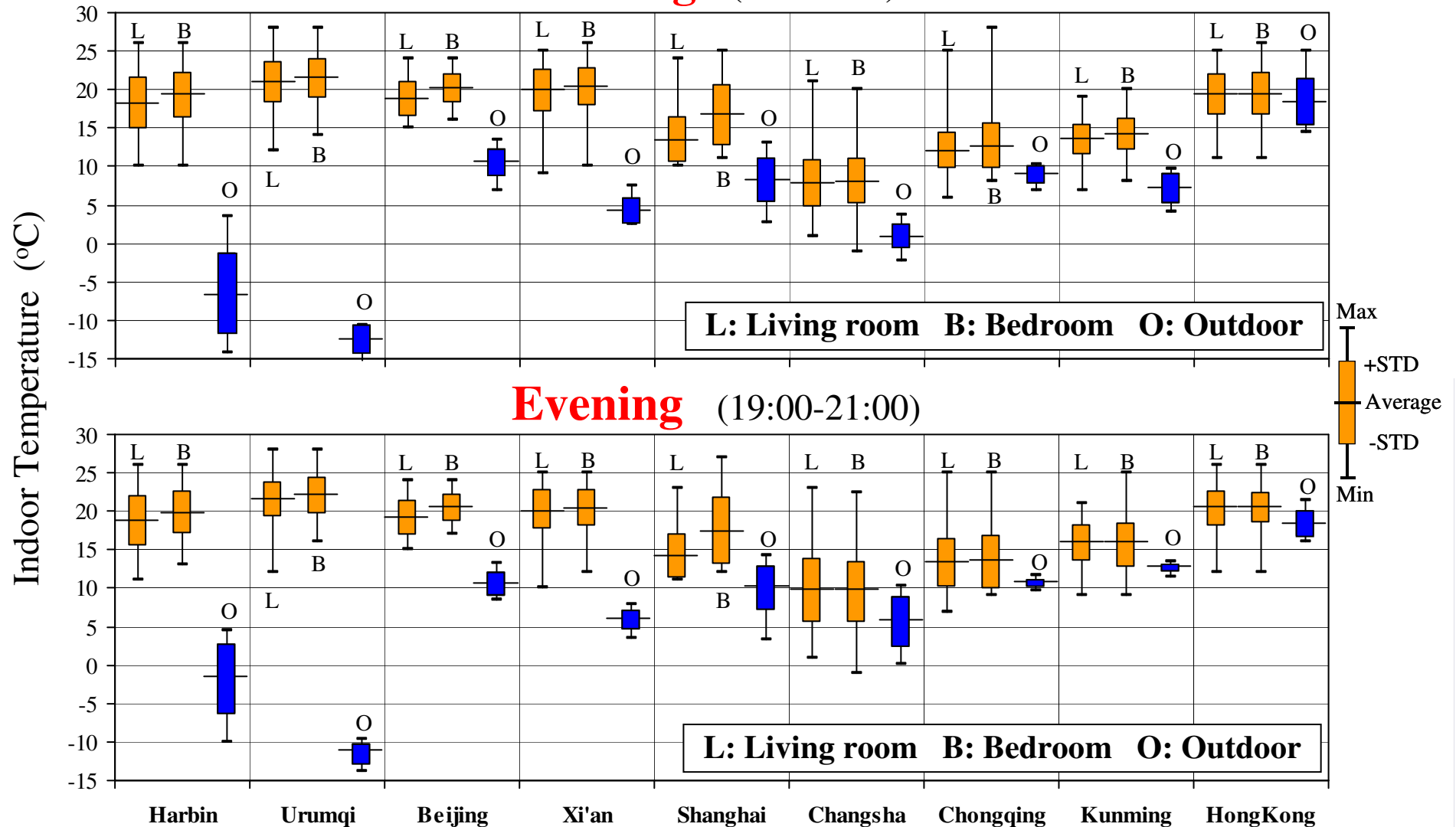


# Ratio of heating system operating in a day

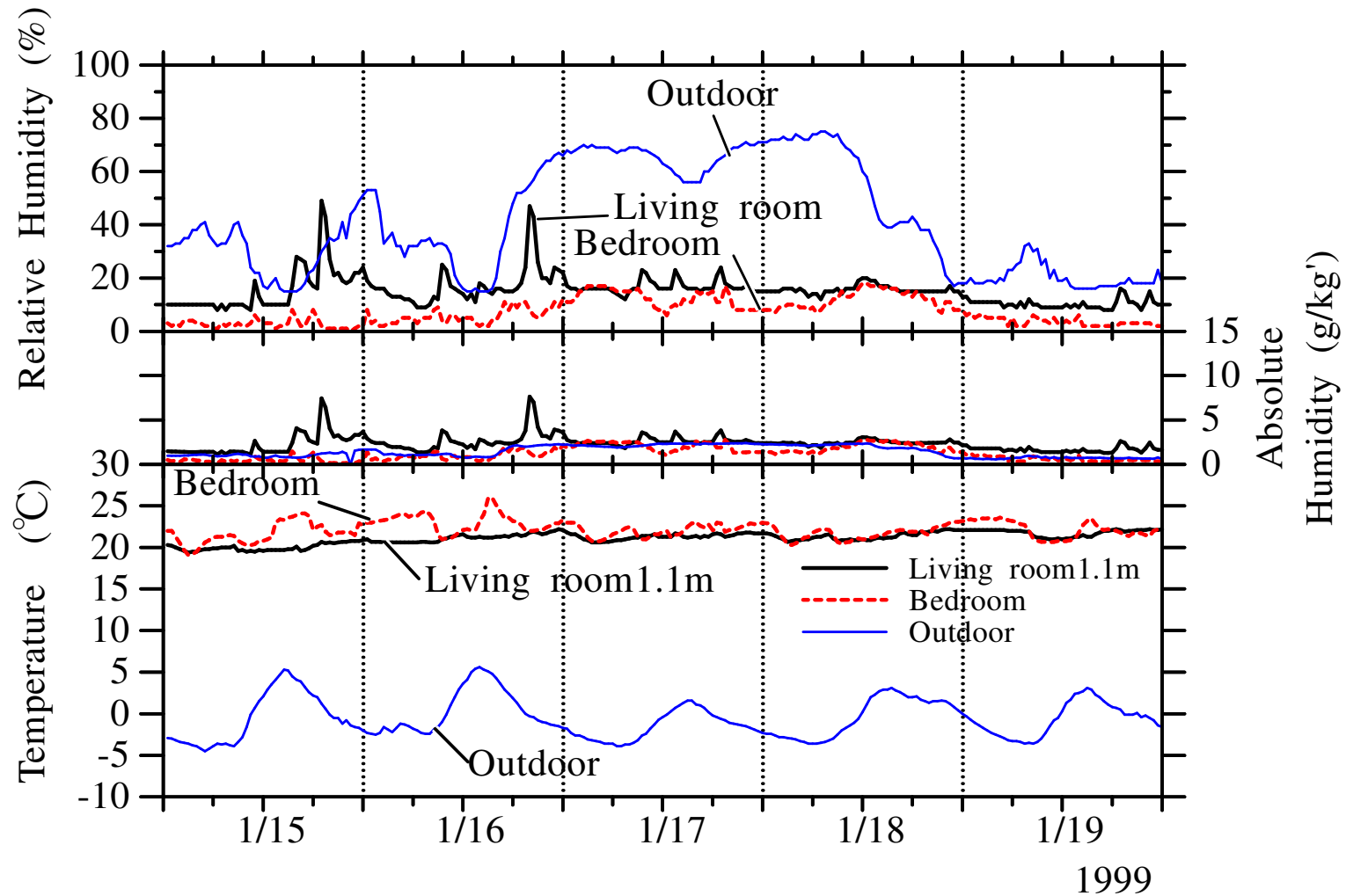


# Temperature distribution of living room, bedroom and outdoor

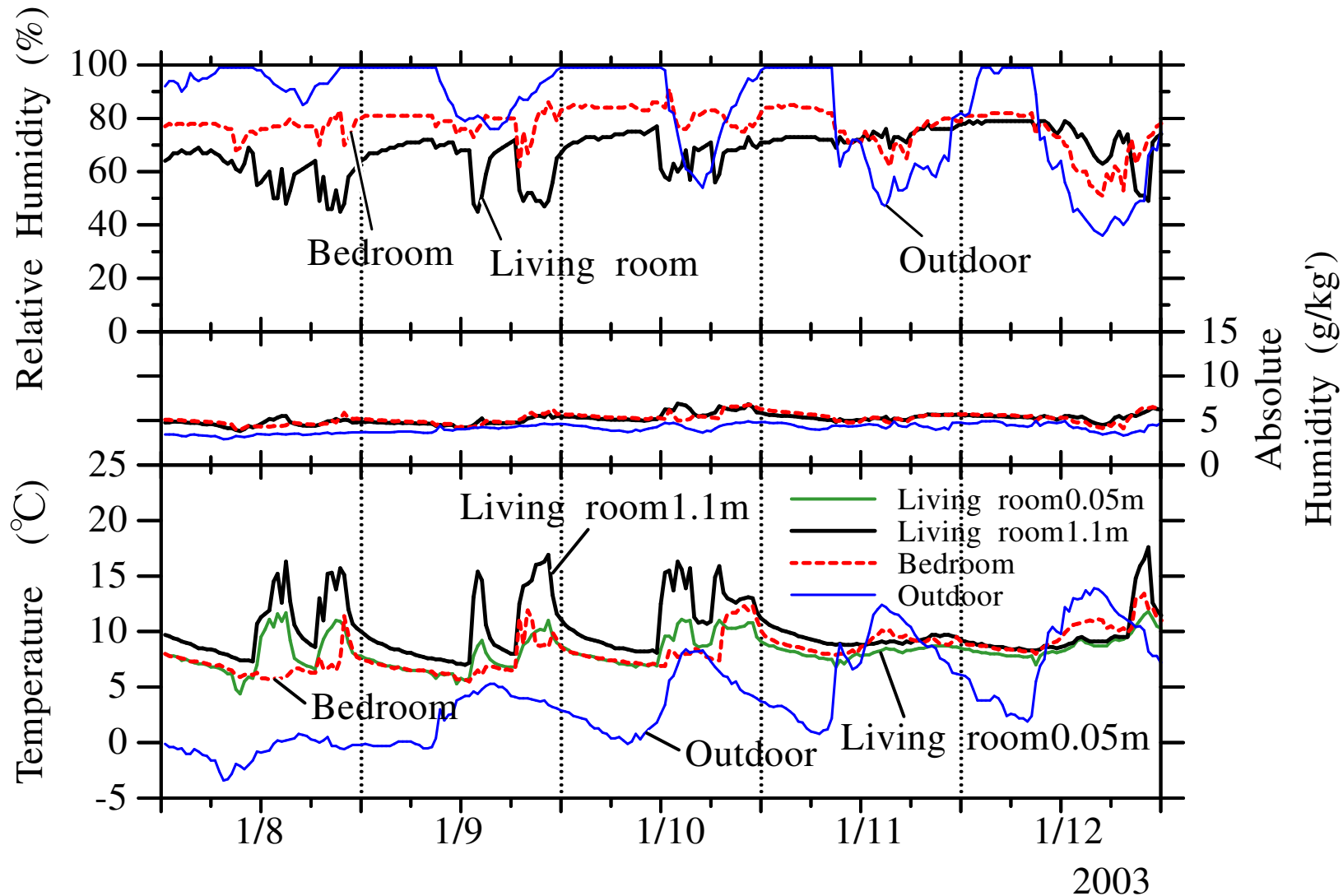
**Morning** (6:00-8:00)



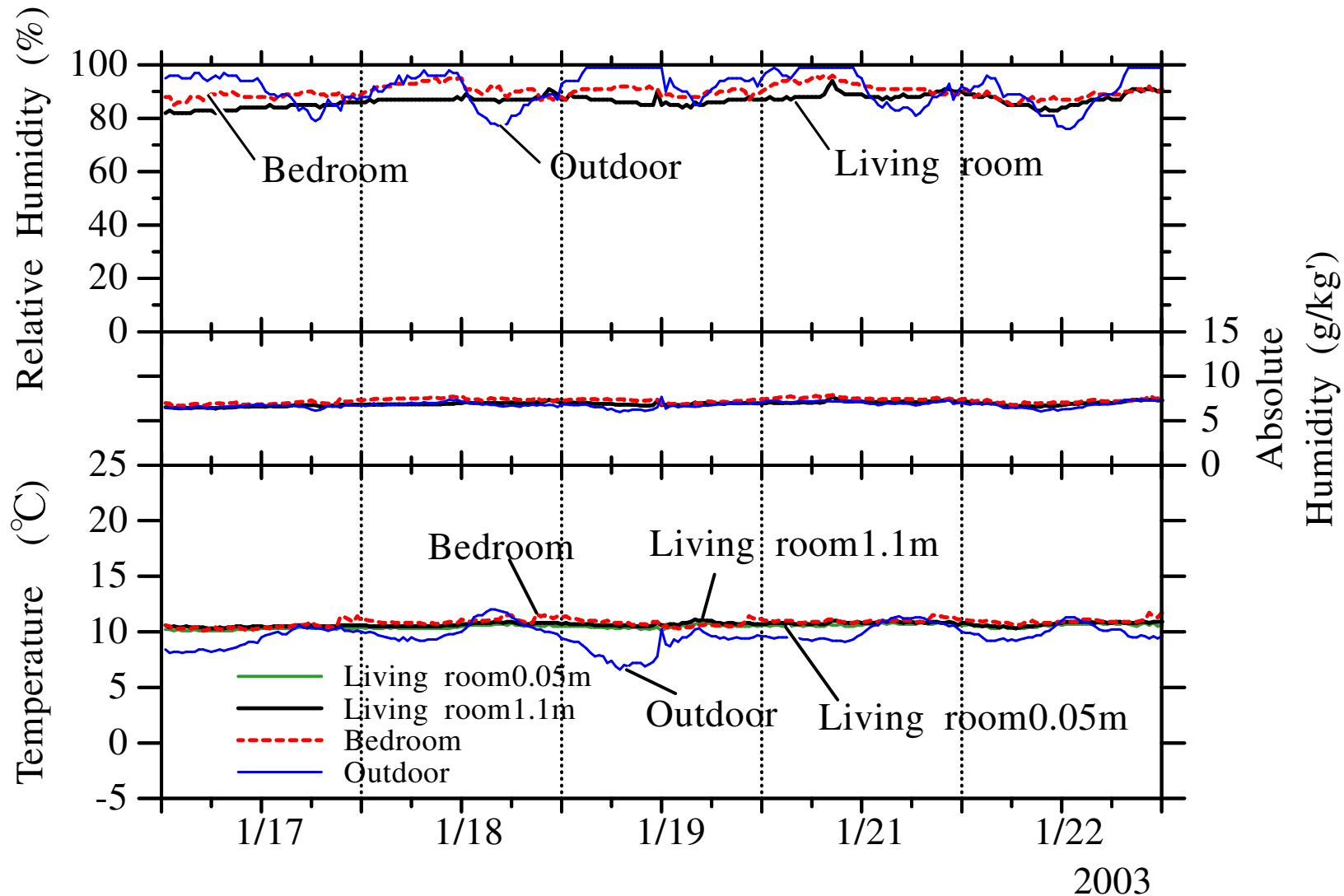
# An example of the time variation of temperature and humidity (Beijing)



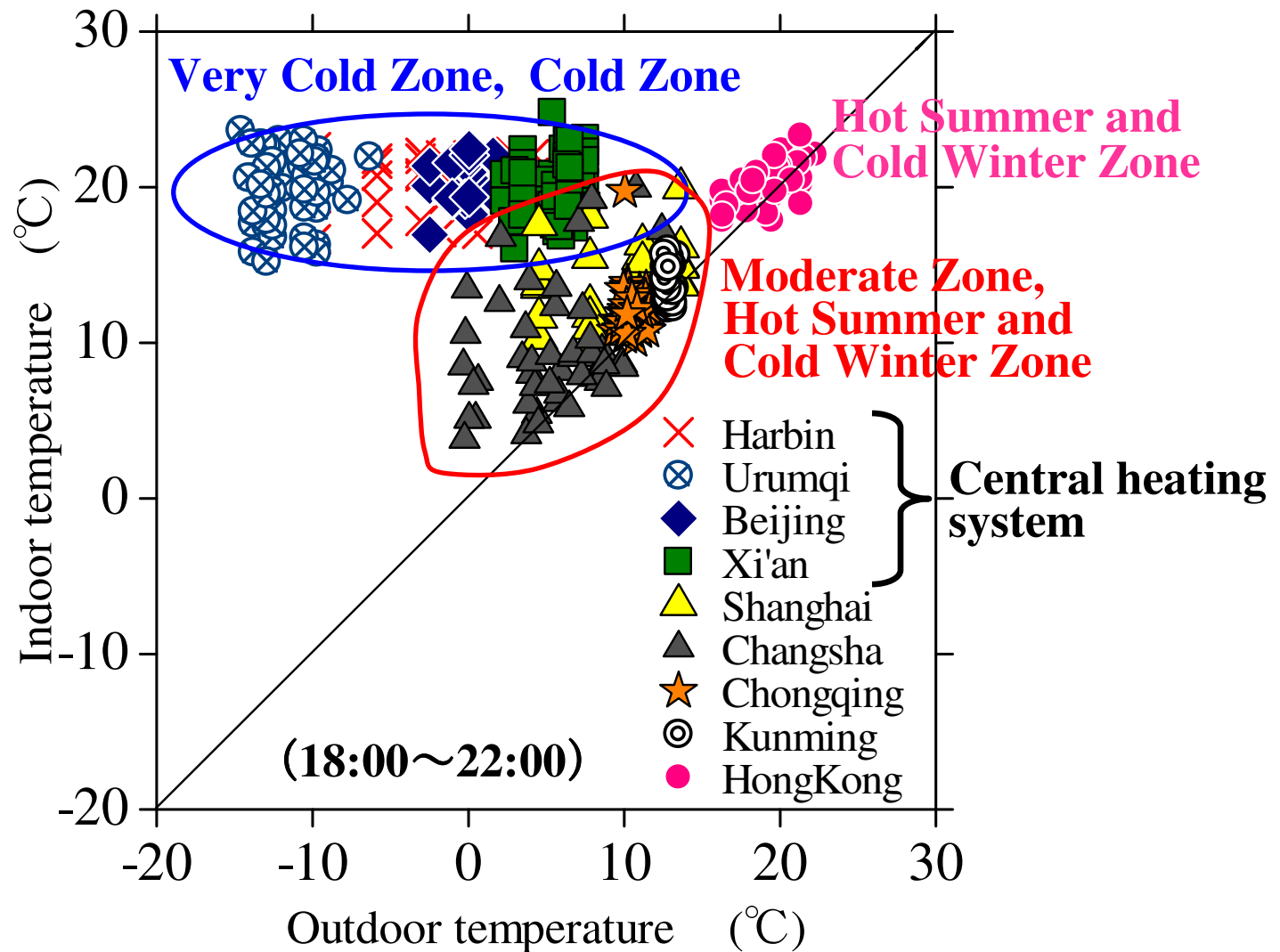
# An example of the time variation of temperature and humidity (Changsha)



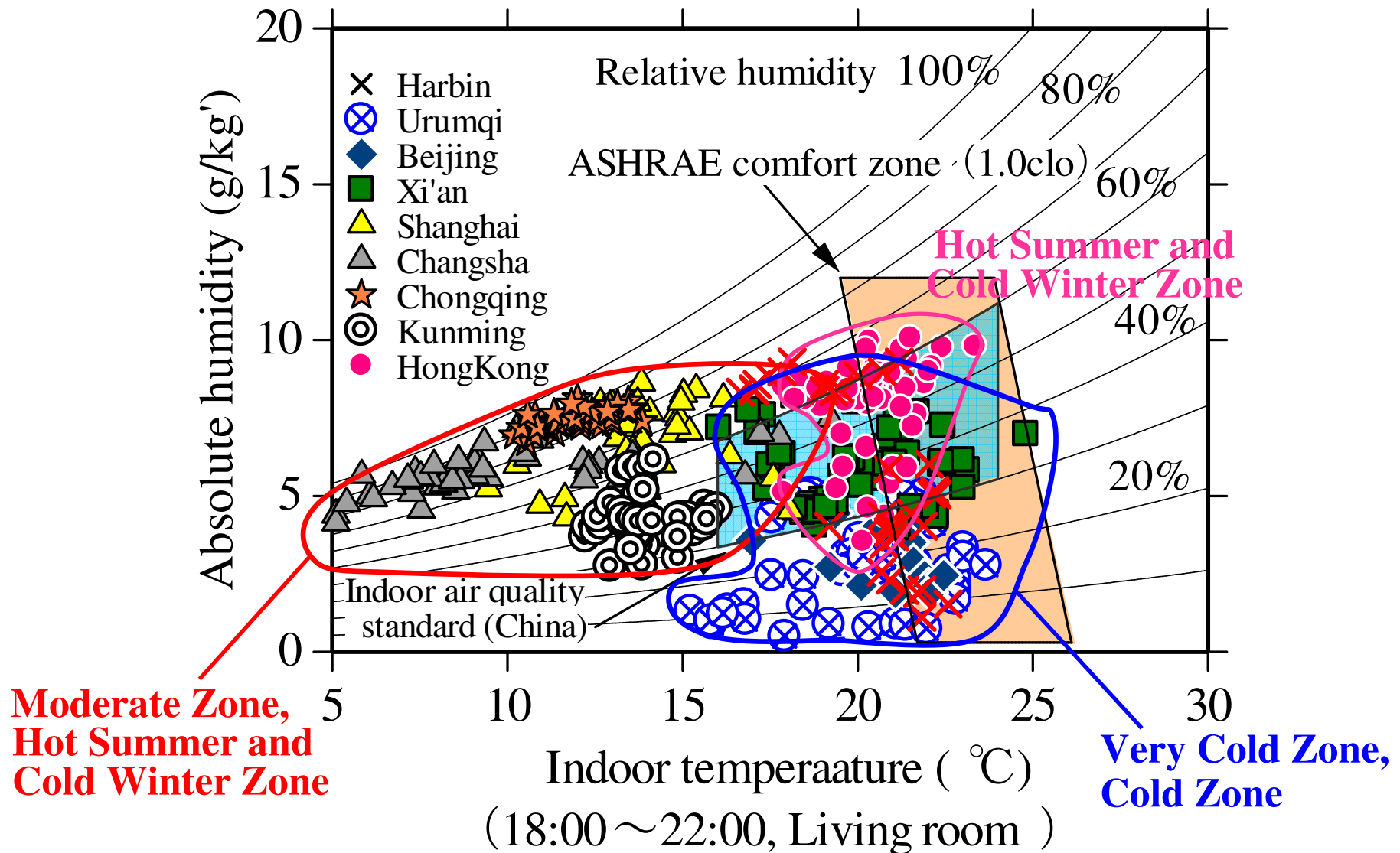
# An example of the time variation of temperature and humidity (Chongqing)



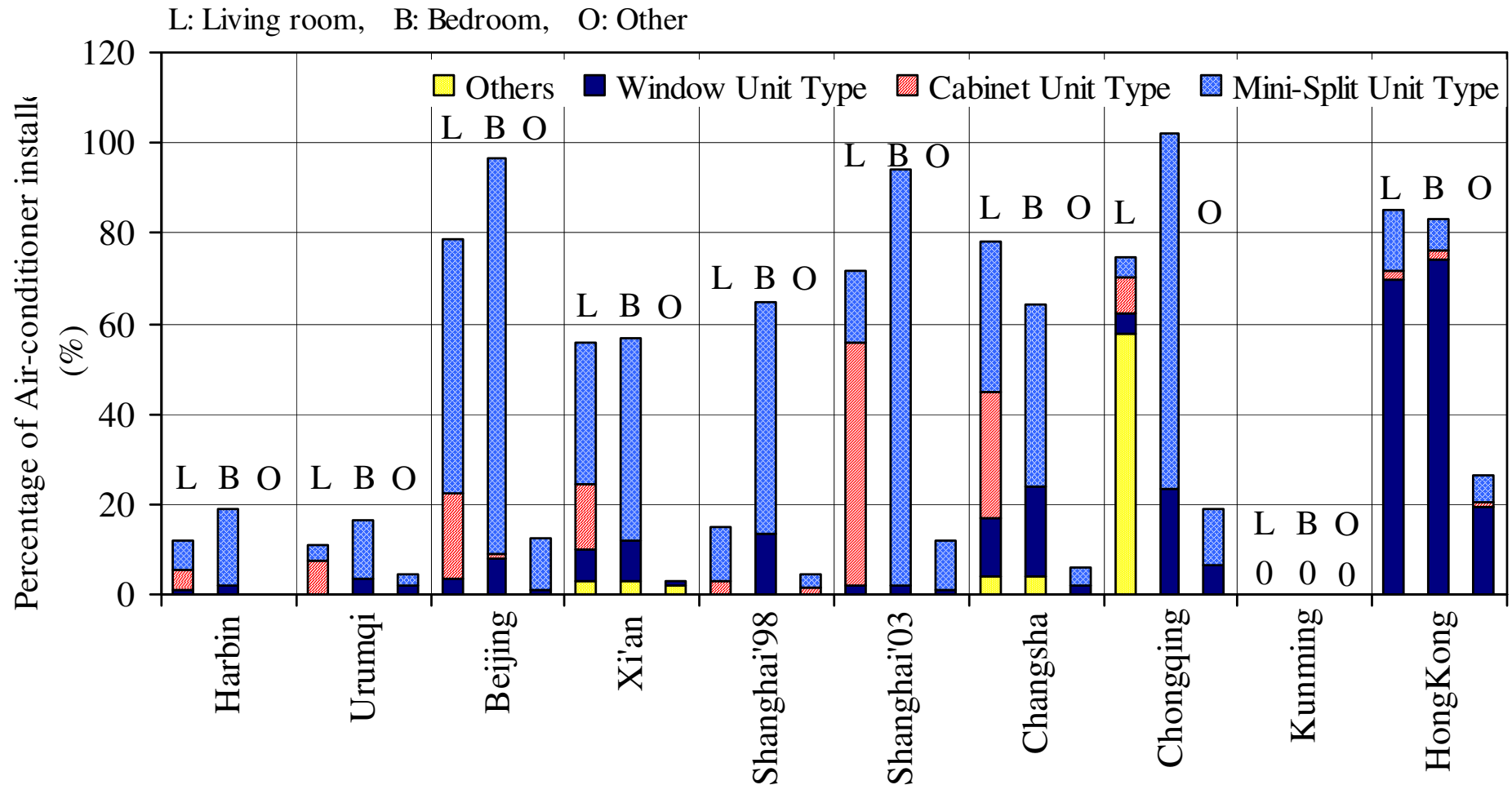
# Correlation between indoor and outdoor temperature (evening hours, 18:00-22:00)



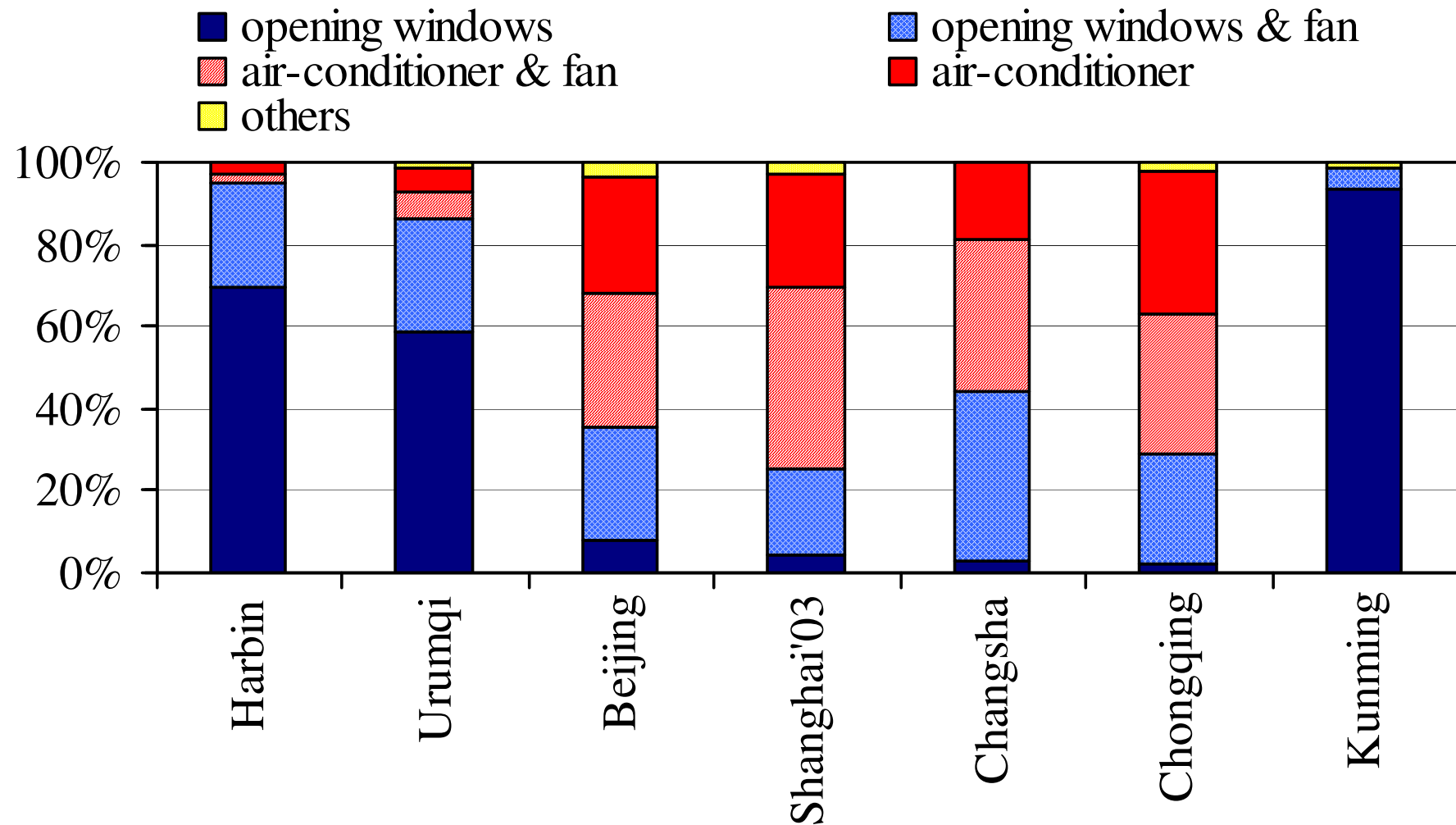
# Thermal comfort of each city (evening hours, 18:00-22:00, Living room)



# Ratio of apartments with air-conditioner

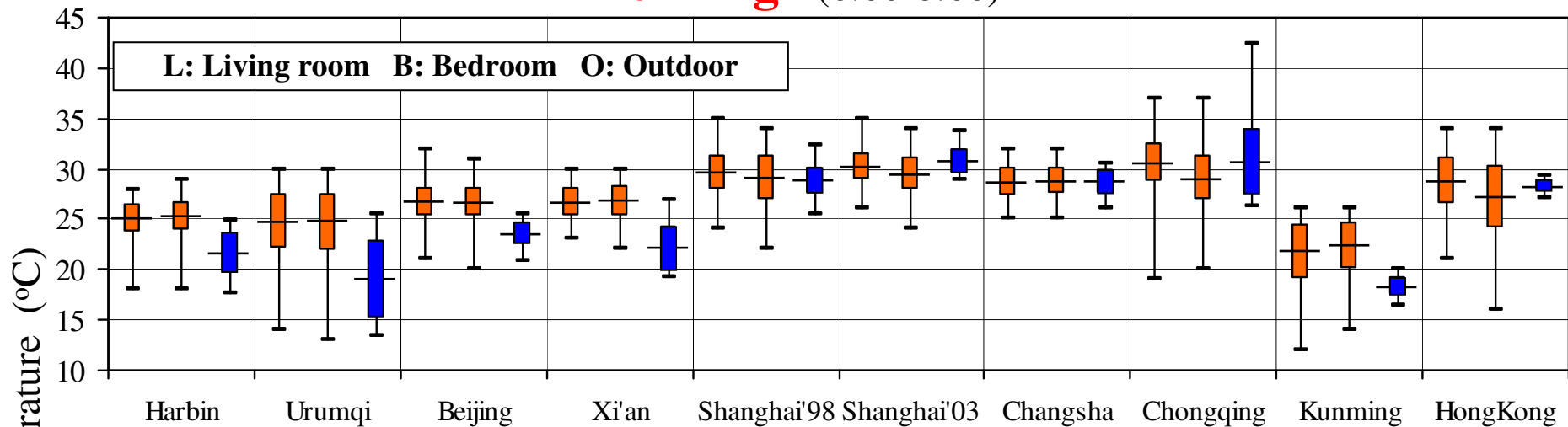


# Way of cooling

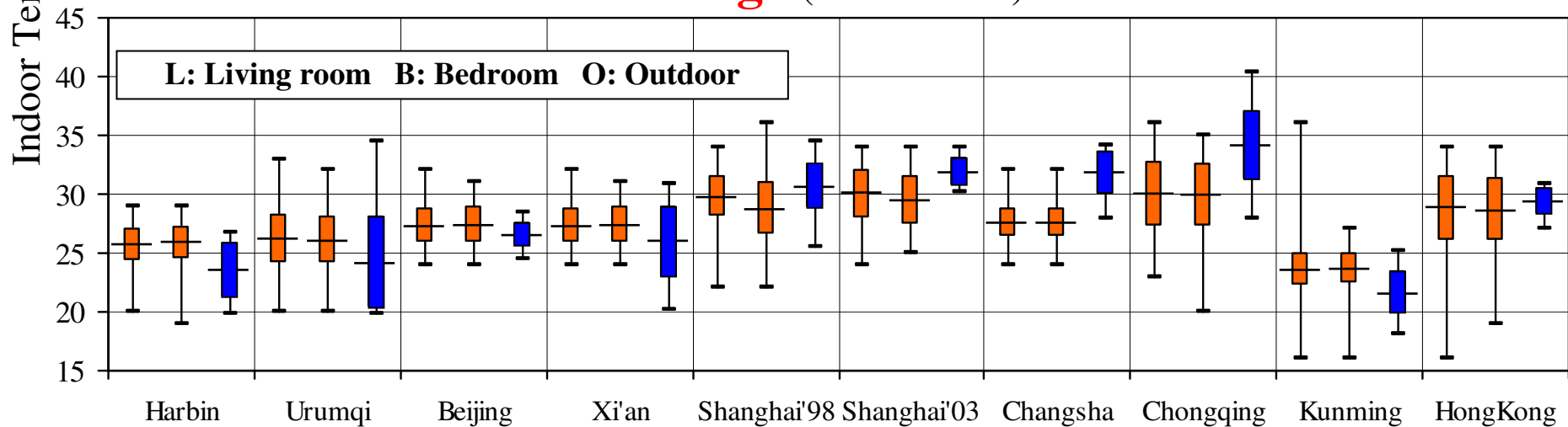


# Temperature distribution of living room, bedroom and outdoor

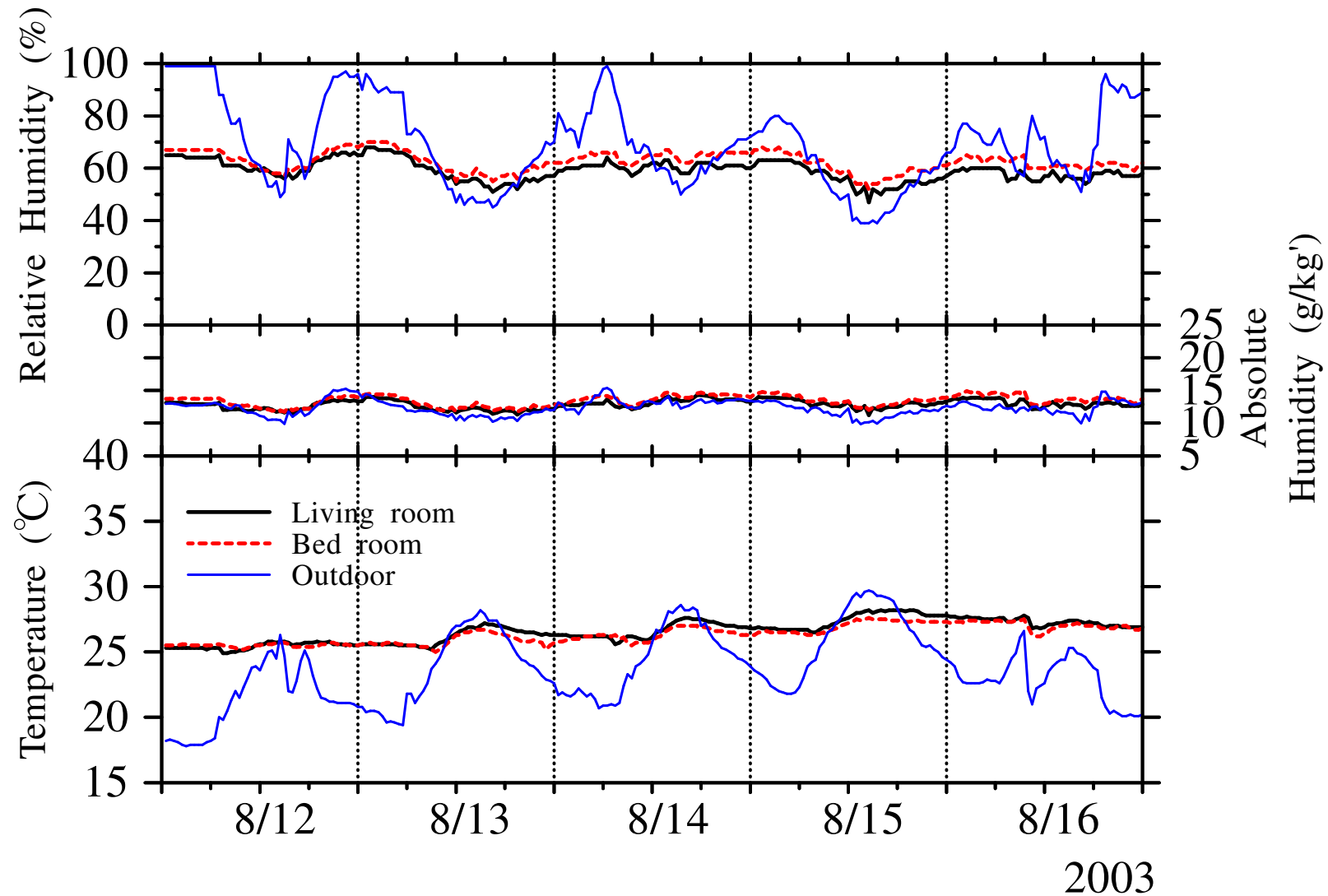
**Morning** (6:00-8:00)



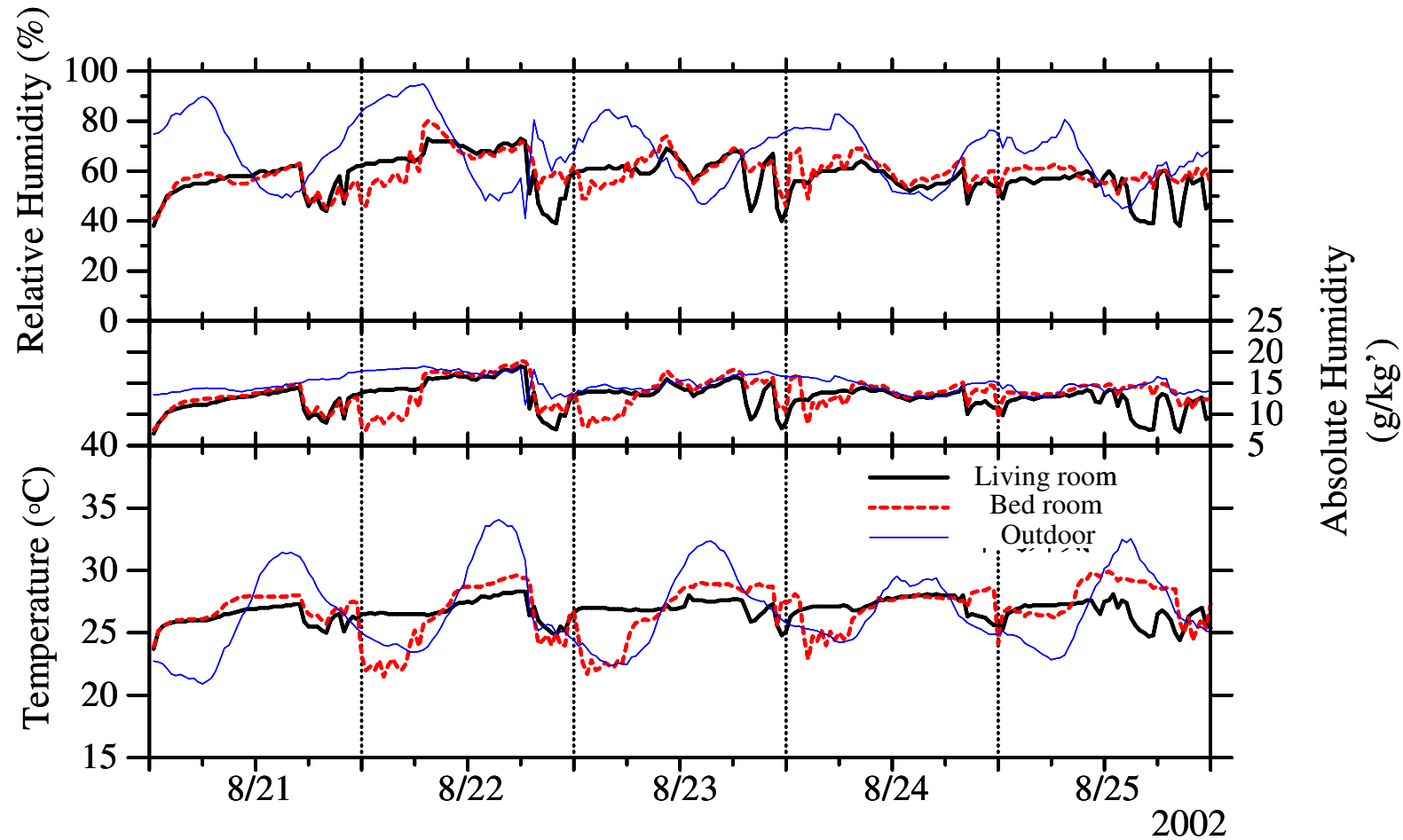
**Evening** (19:00-21:00)



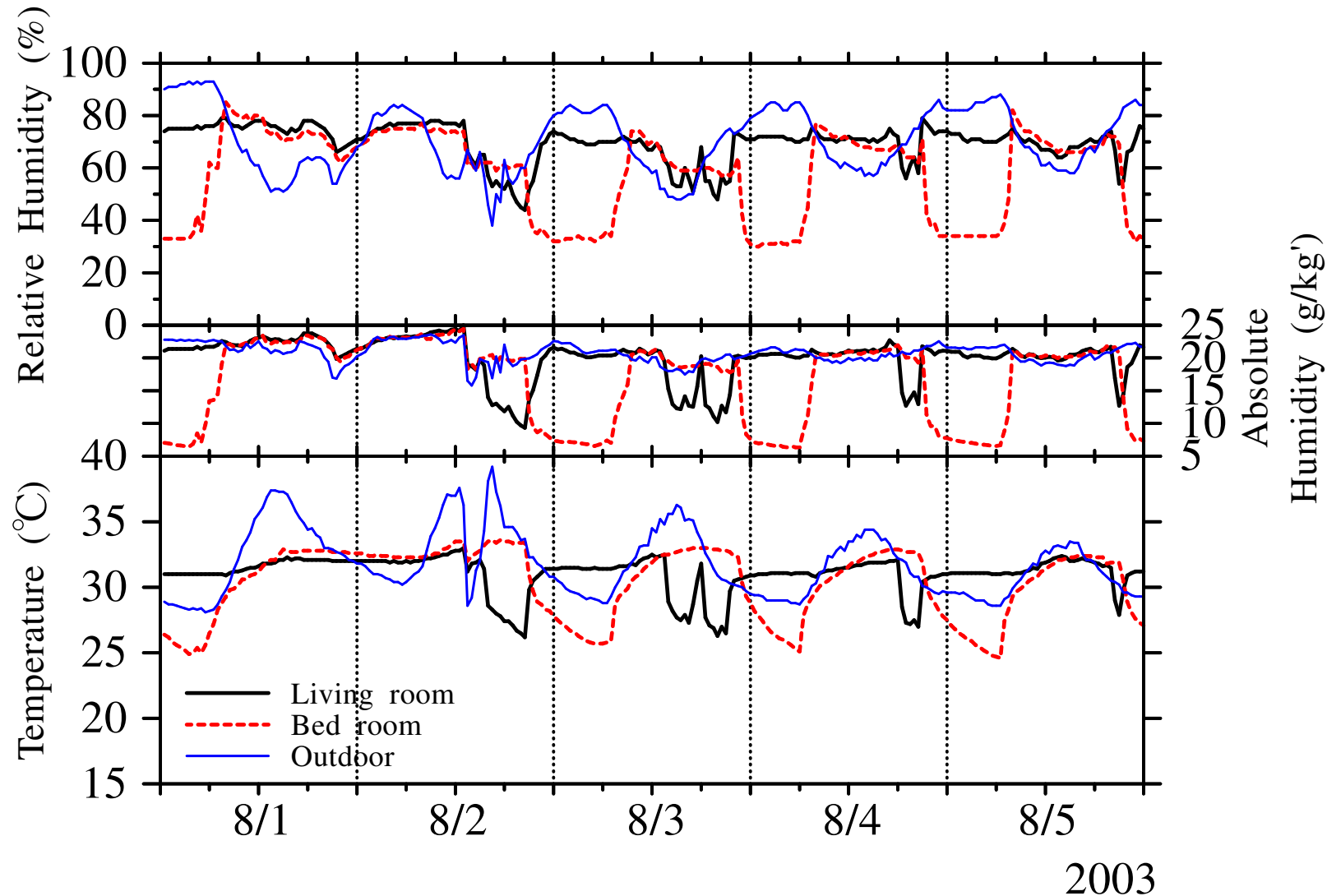
# An example of the time variation of temperature and humidity (Harbin)



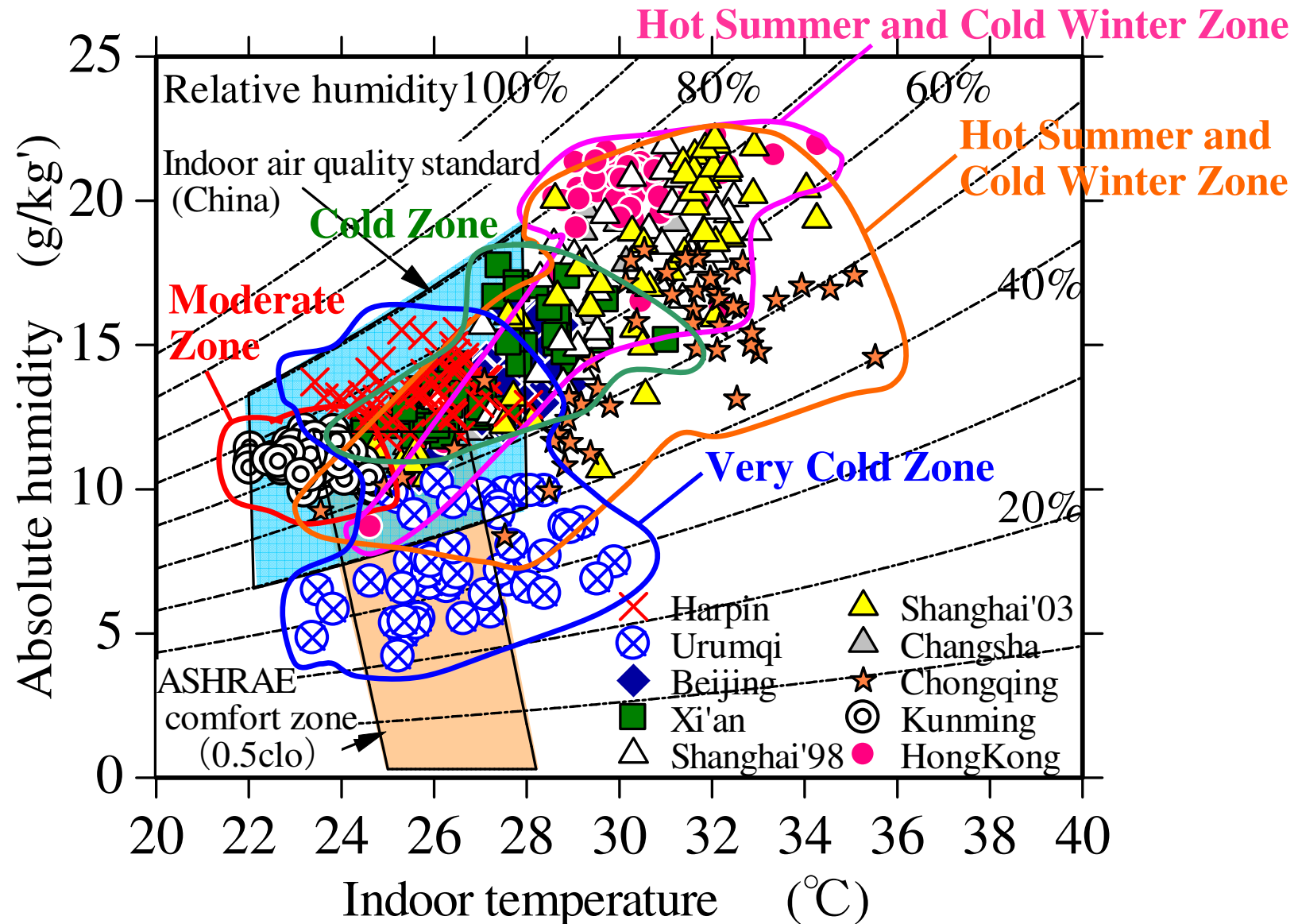
# An example of the time variation of temperature and humidity (Beijing)



# An example of the time variation of temperature and humidity (Shanghai)



# Thermal comfort of each city (evening hours, 18:00-22:00, Living room)



# CONTENTS

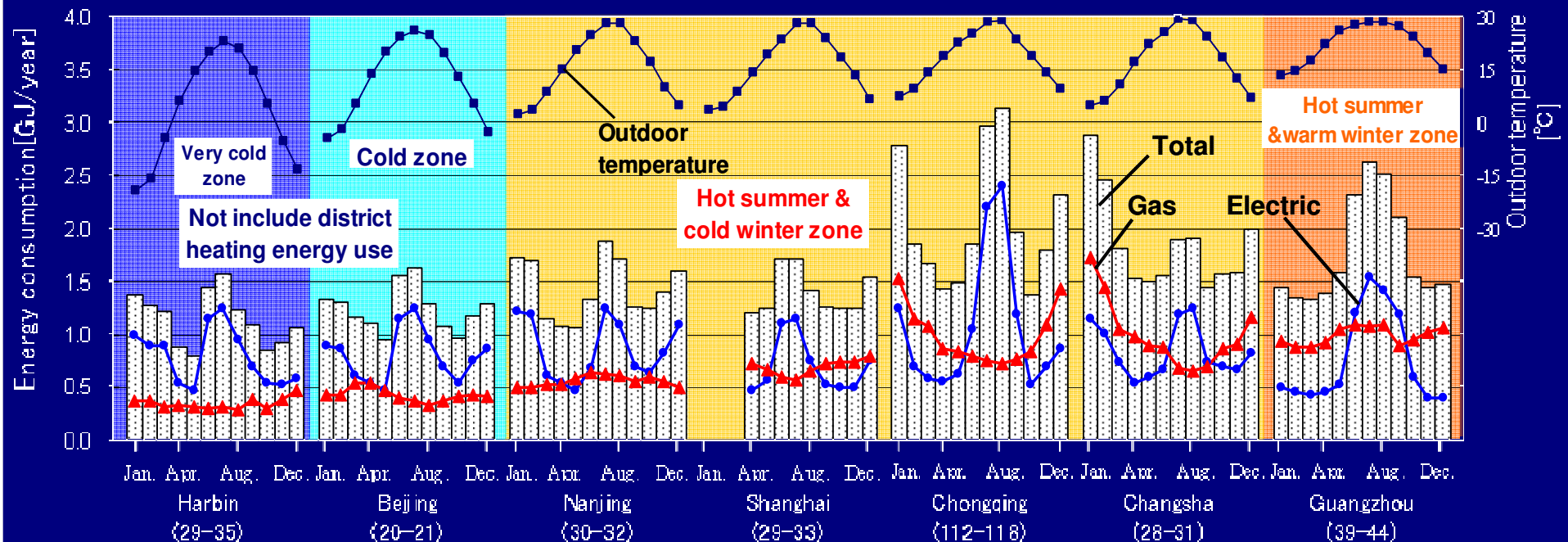
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- 2. Overview of CO<sub>2</sub> emission & energy consumption in the world**
- 3. Energy use in China**
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- 7. Conclusion remarks**

# Location of the cities investigated

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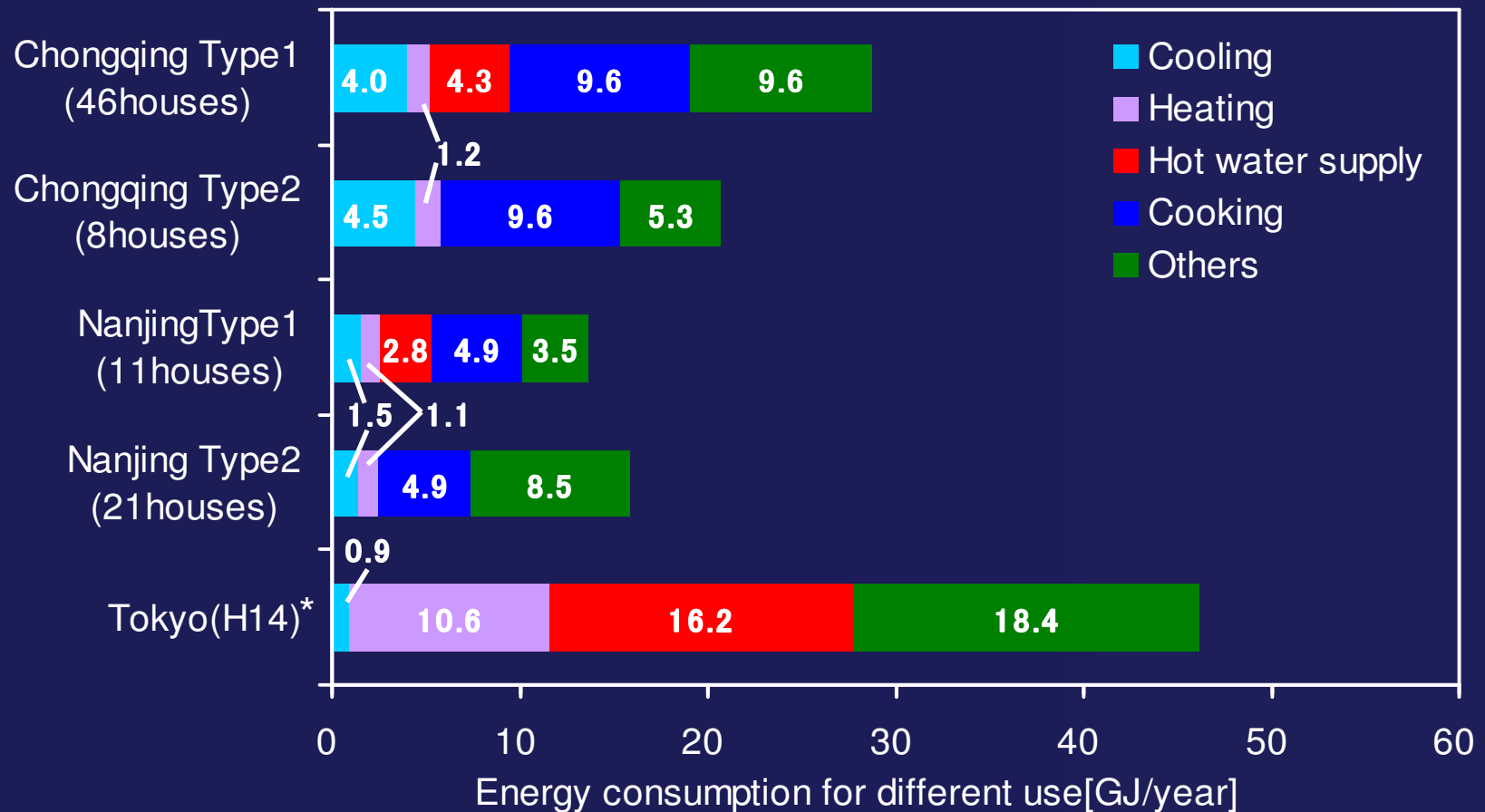


# Monthly energy consumption and outdoor temperature in 7 cities



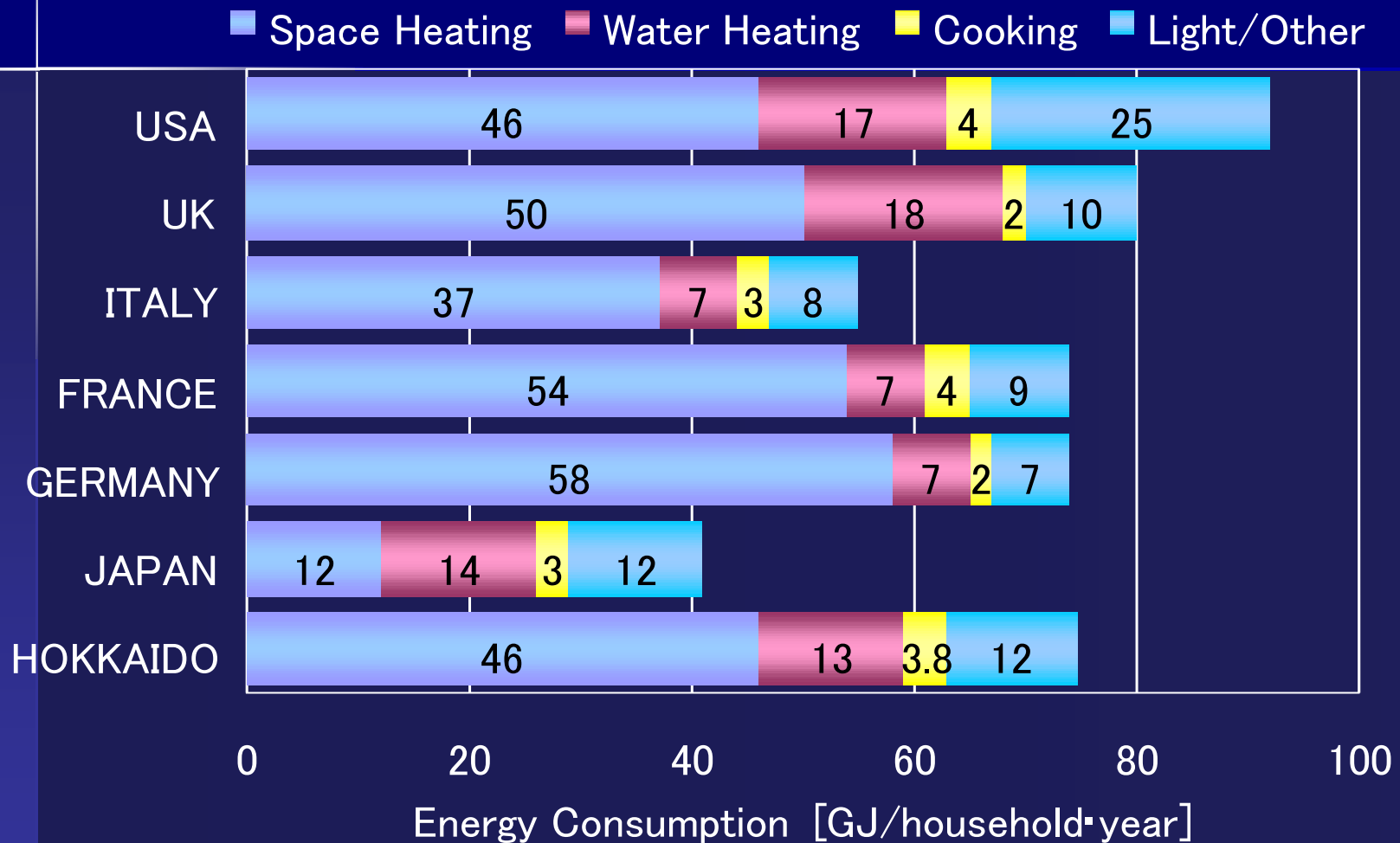
- **Electric:** The consumption of all cities is influenced by the outdoor temperature. There is a consumption peak in summer and Chongqing's energy consumption is twice as the other cities'.
- **Gas:** Consumption of south China is more than that of North China. In Southern cities such as Changsha and Chongqing, where people prefer cooking.

# Energy consumption and end use



\*Reference: The energy data and modeling center in Japan, 06  
Energy & economy statistics handbook

# Residential energy comparison in main countries



# Measurement methods

Measurement methods	Measurement	Time interval	Location
Home energy consumption recording system	Electricity consumption & Electricity generation by PV	1 Minute	
Camera type color image data logger	Gas consumption	5 Minutes	Kitchen
Small sensor & data logger	Temperature & relative humidity	30 Minutes	Outside & Livingroom & Bedroom



Home energy consumption recording system



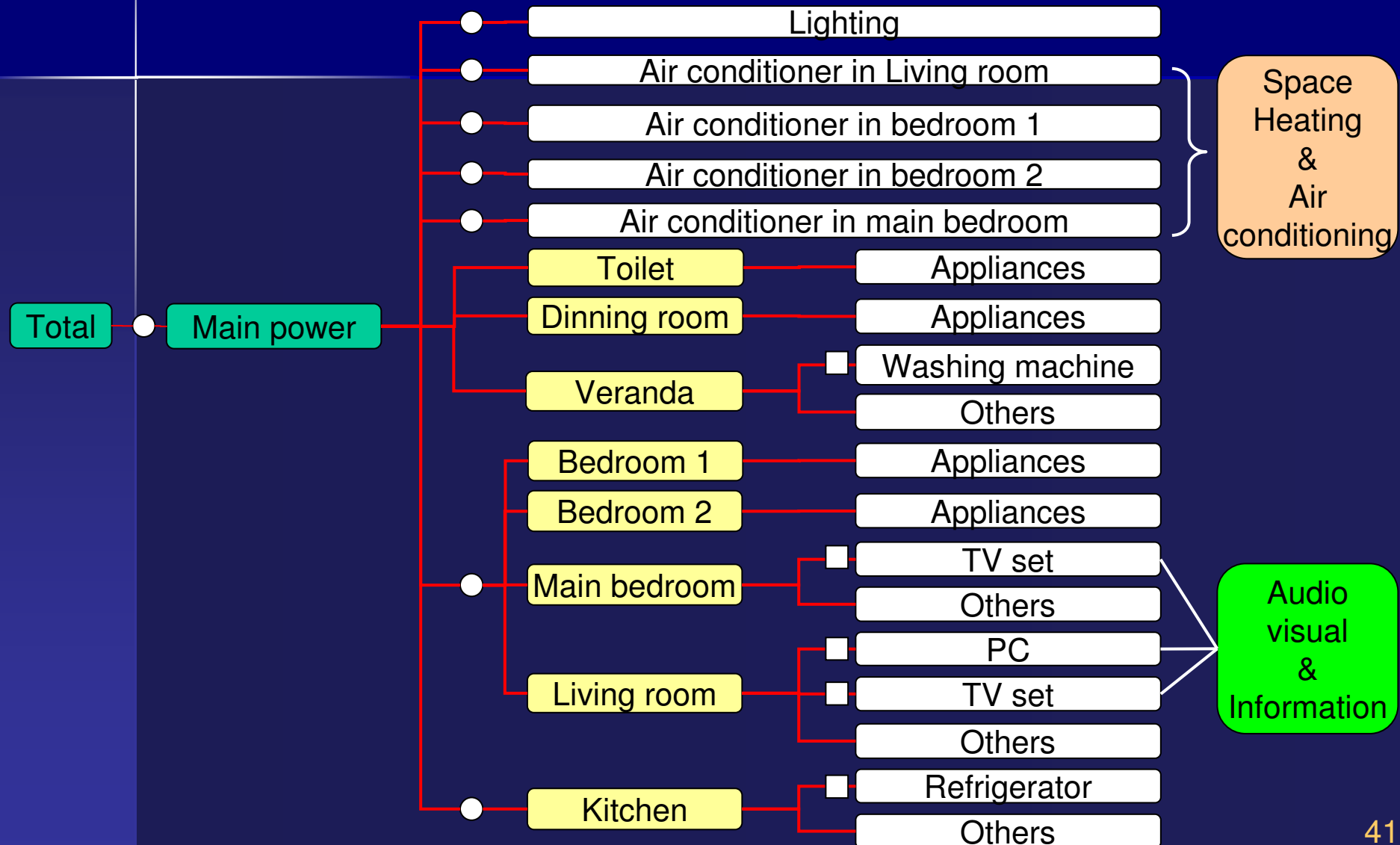
Camera type color image data logger



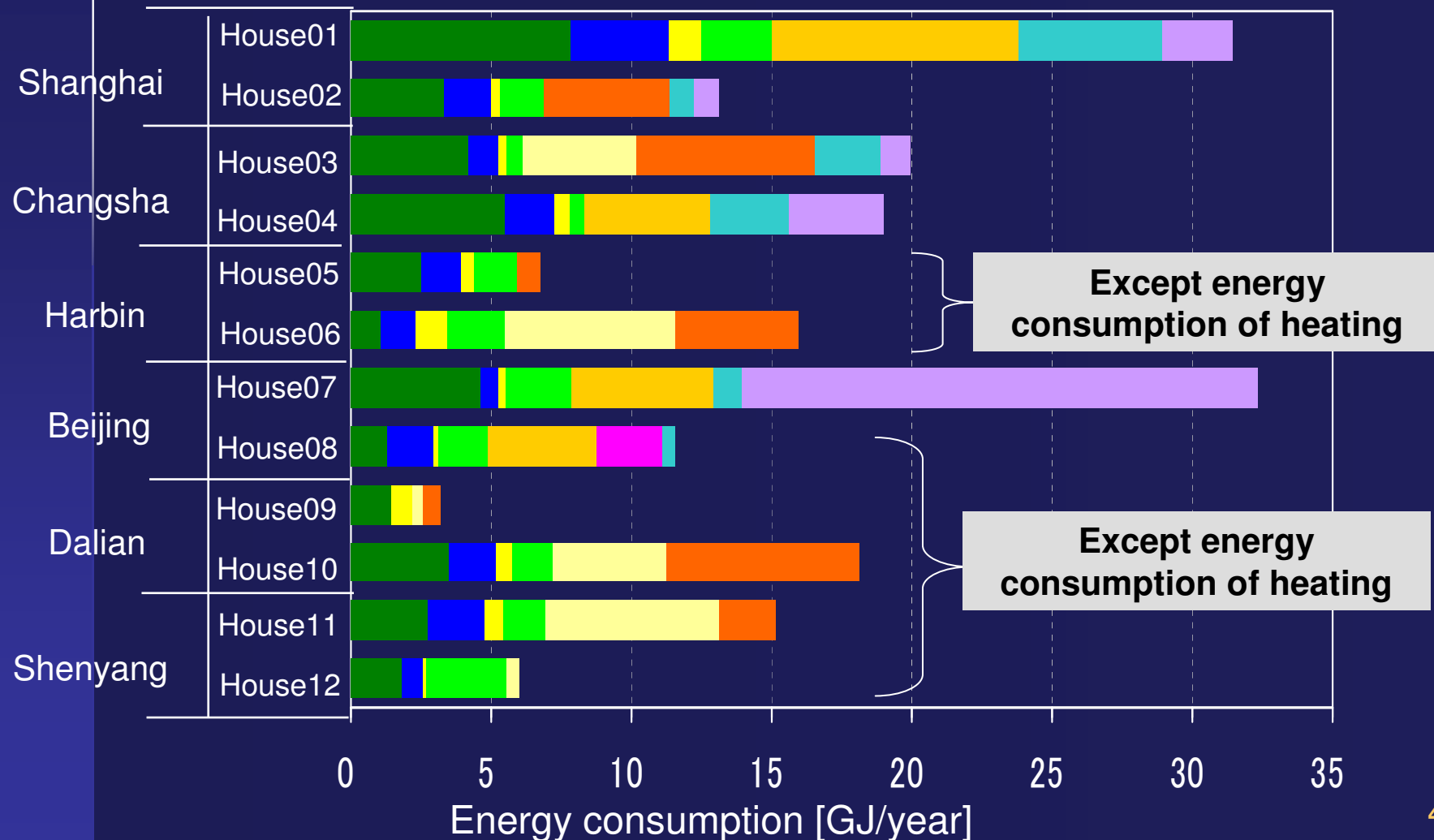
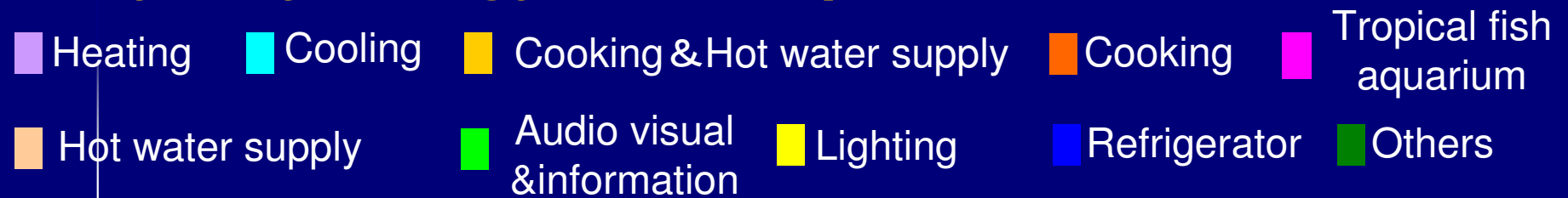
Small sensor & data logger

# Electricity distribution system and location of meters for an apartment

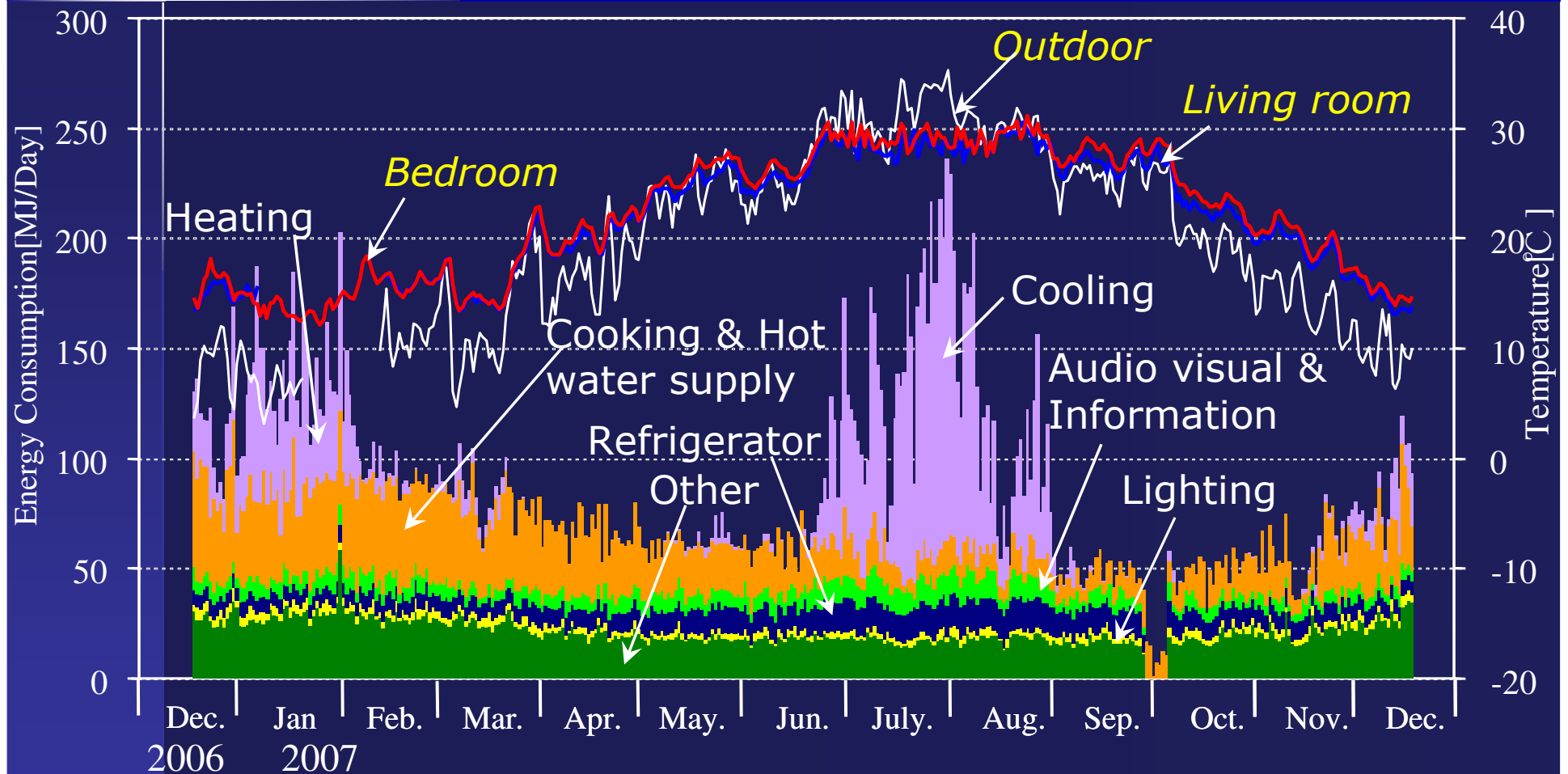
- Wattmeter in electricity distribution panel
- Wattmeter on electric outlet



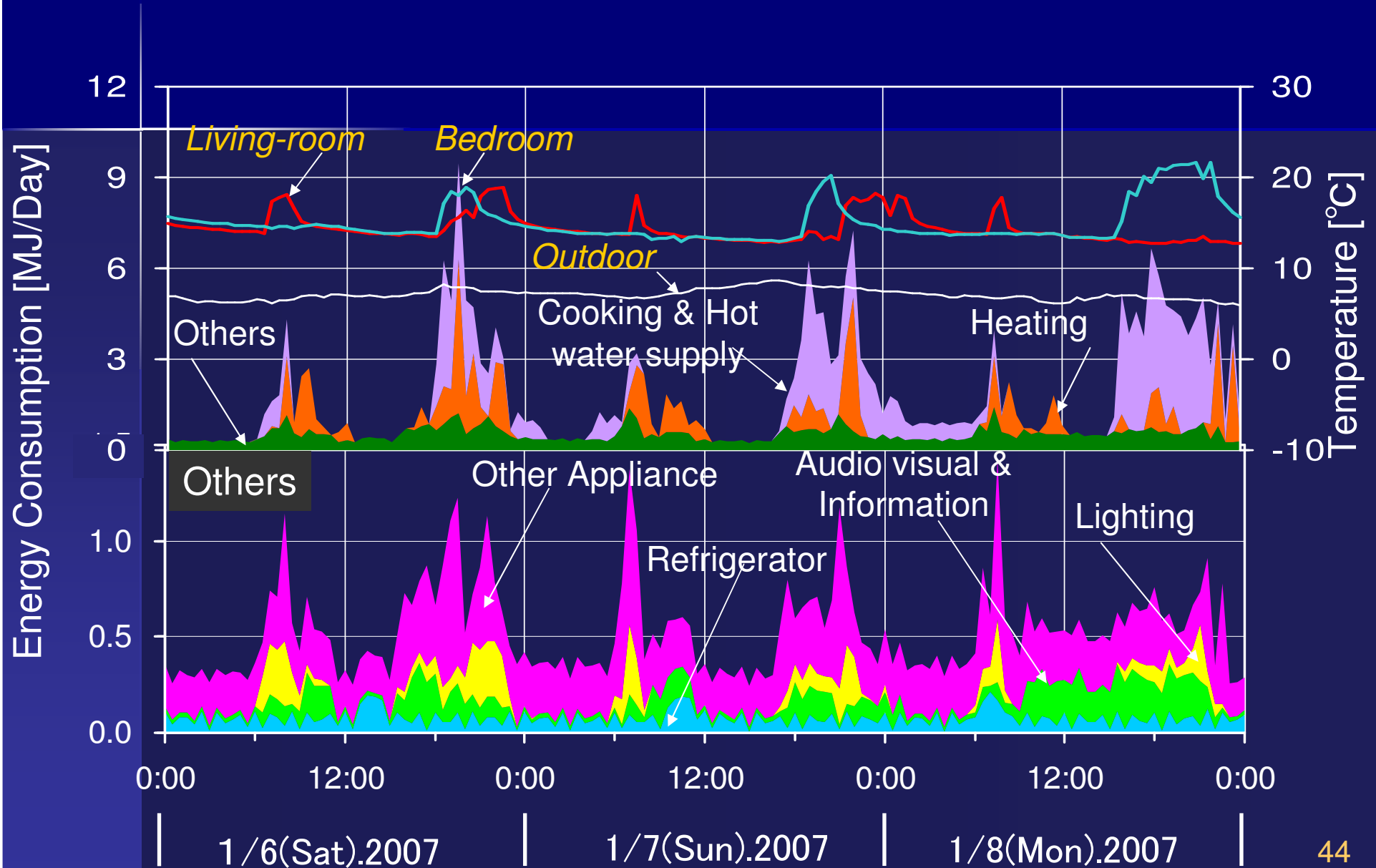
# The yearly Energy Consumption of the 12 Houses



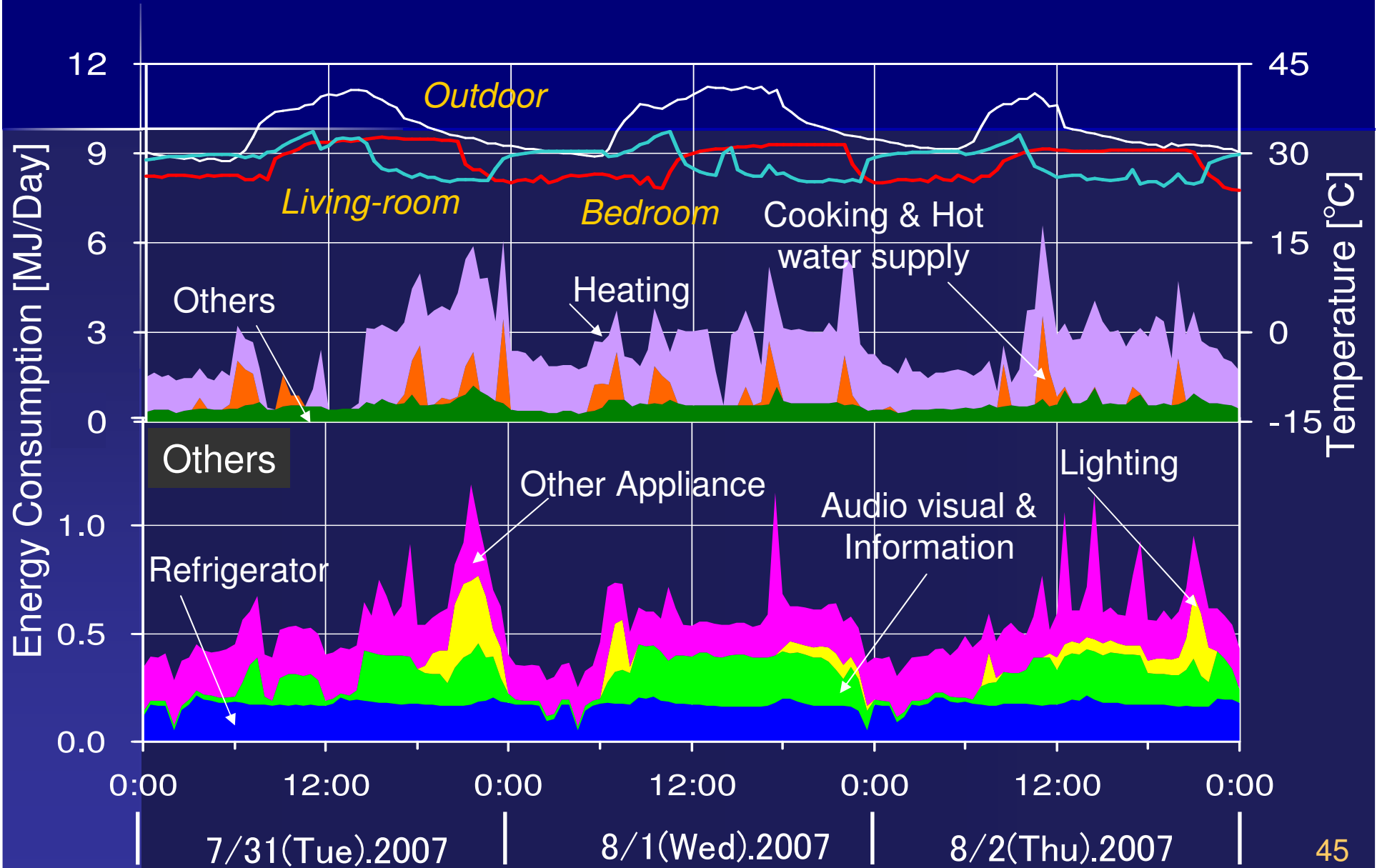
# Shanghai 01 (18 Dec. 2006 ~ 20 Dec. 2007)



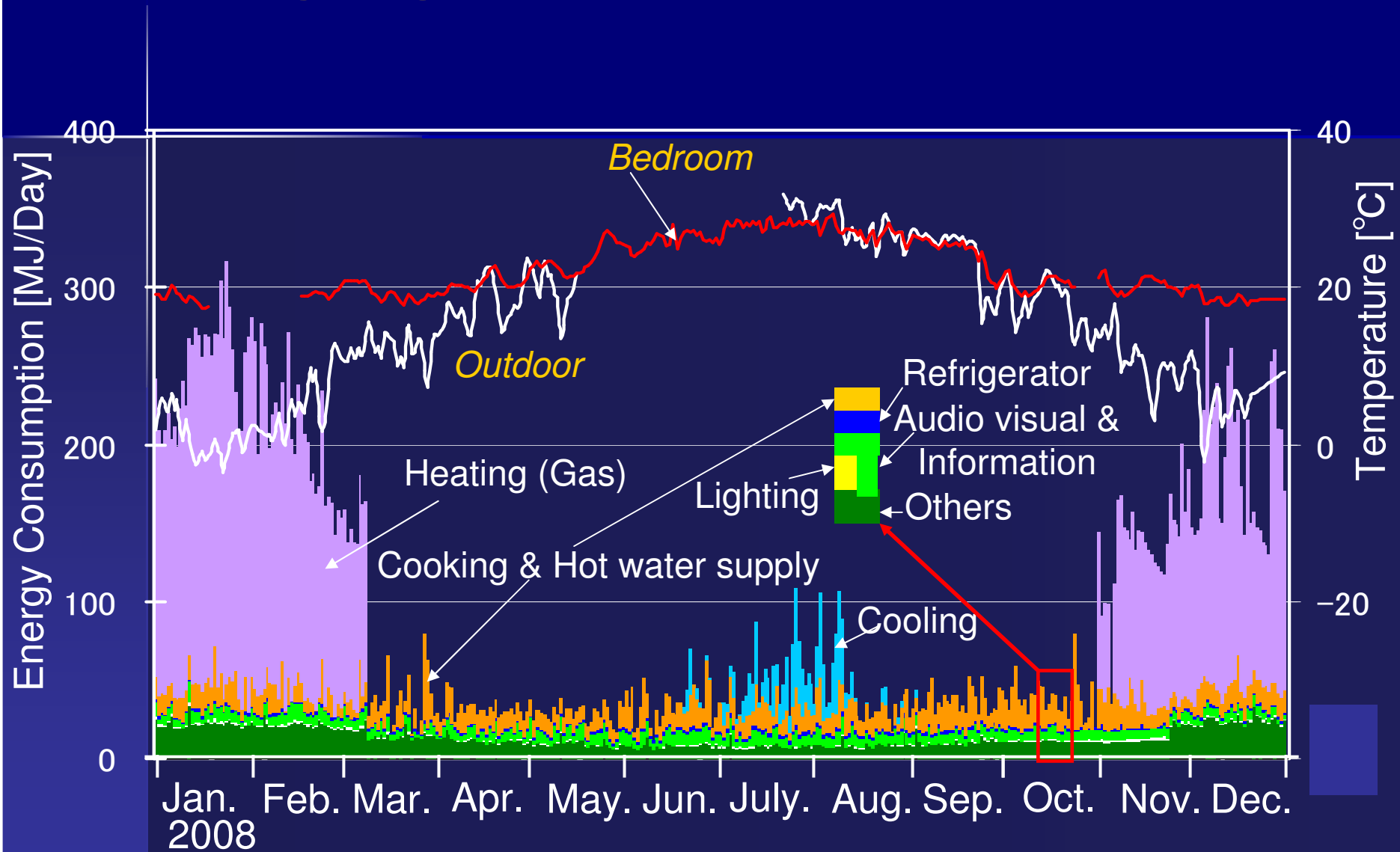
# Shanghai 01 (Coldest days)



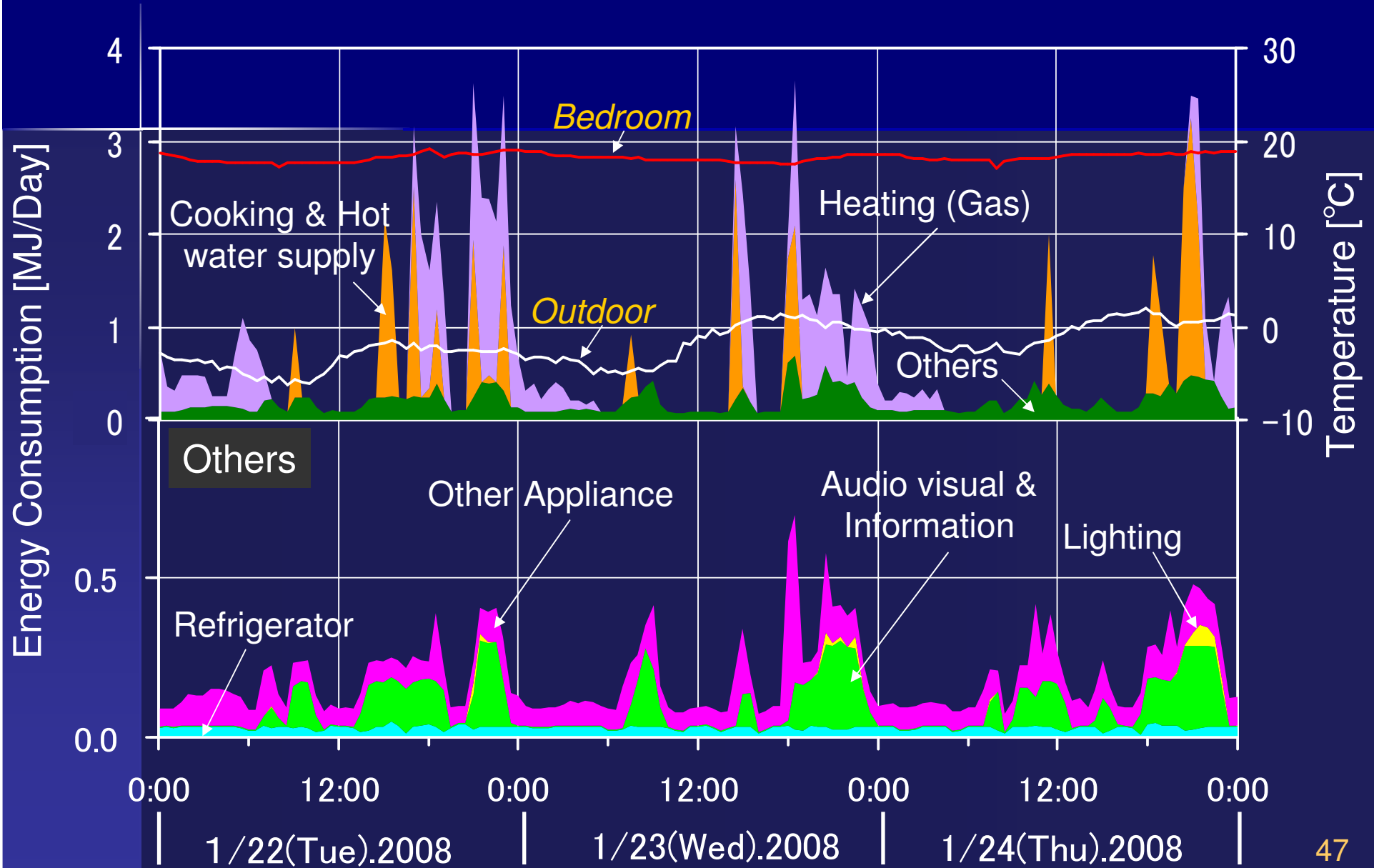
# Shanghai 01 (hottest days)



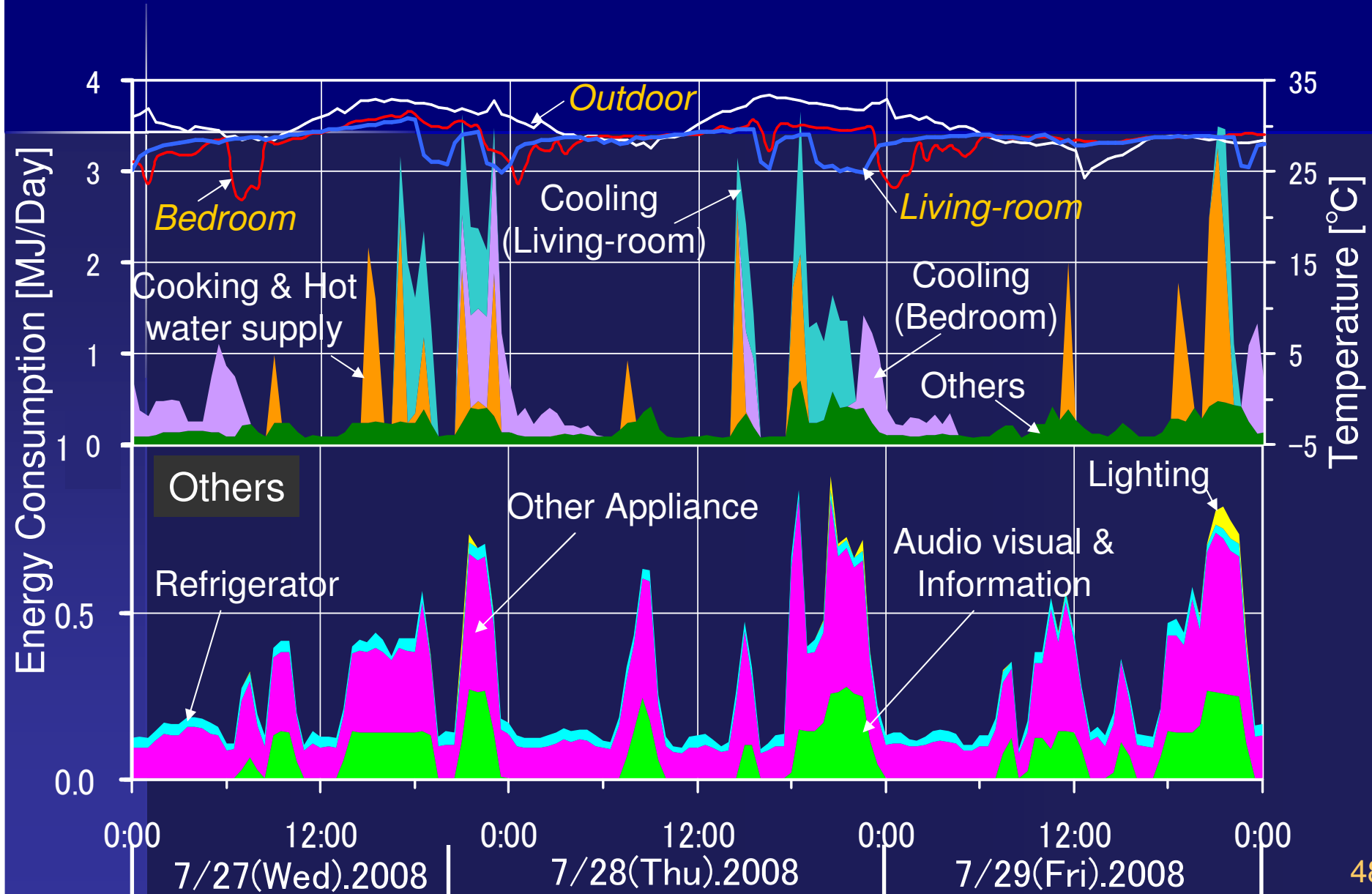
# Beijing 07 (01 Jan. 2008 ~ 31 Dec. 2008)



# Beijing 07 (Coldest days)



# Beijing 07 (hottest days)



# CONTENTS

- 1. Introduction**
- 2. Overview of CO<sub>2</sub> emission & energy consumption in the world**
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# Model apartment for the calculation

## Features

- The living room is not on a center of the house.
- Use the balcony as outdoors.
- The brick is used for the wall.



**Floor Plan of the model house**  
RC-Brick Mixed structure,  
Floor : 87.2m<sup>2</sup>

# Conditions for the calculation

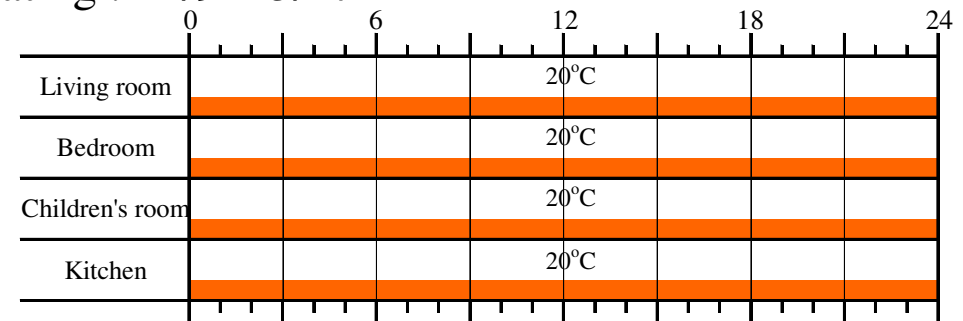
## Cities for calculation:

**Beijing, Shanghai**

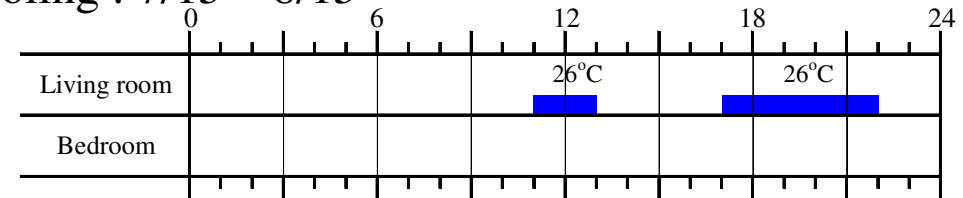
Location	Intermediate floor, Between adjacent apartment units	
Direction	South	
Material of wall	Brick	
Thickness of outer wall	Beijing	370 mm
		$U=1.23 \text{ W/m}^2\cdot\text{K}$
	Shanghai	240 mm
		$U=1.65 \text{ W/m}^2\cdot\text{K}$
Thickness of inner wall	240 mm	
Window	Beijing	Double glazing
	Shanghai	Single glazing

## Air-conditioning schedule -Beijing-

Heating : 11/9 ~ 3/17

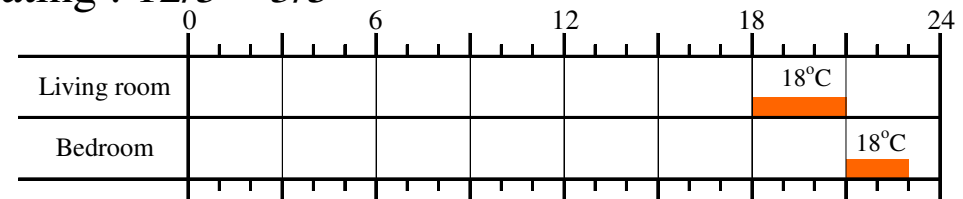


Cooling : 7/15 ~ 8/15

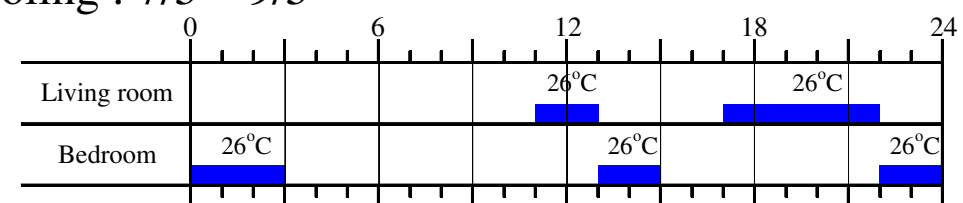


## Air-conditioning schedule -Shanghai-

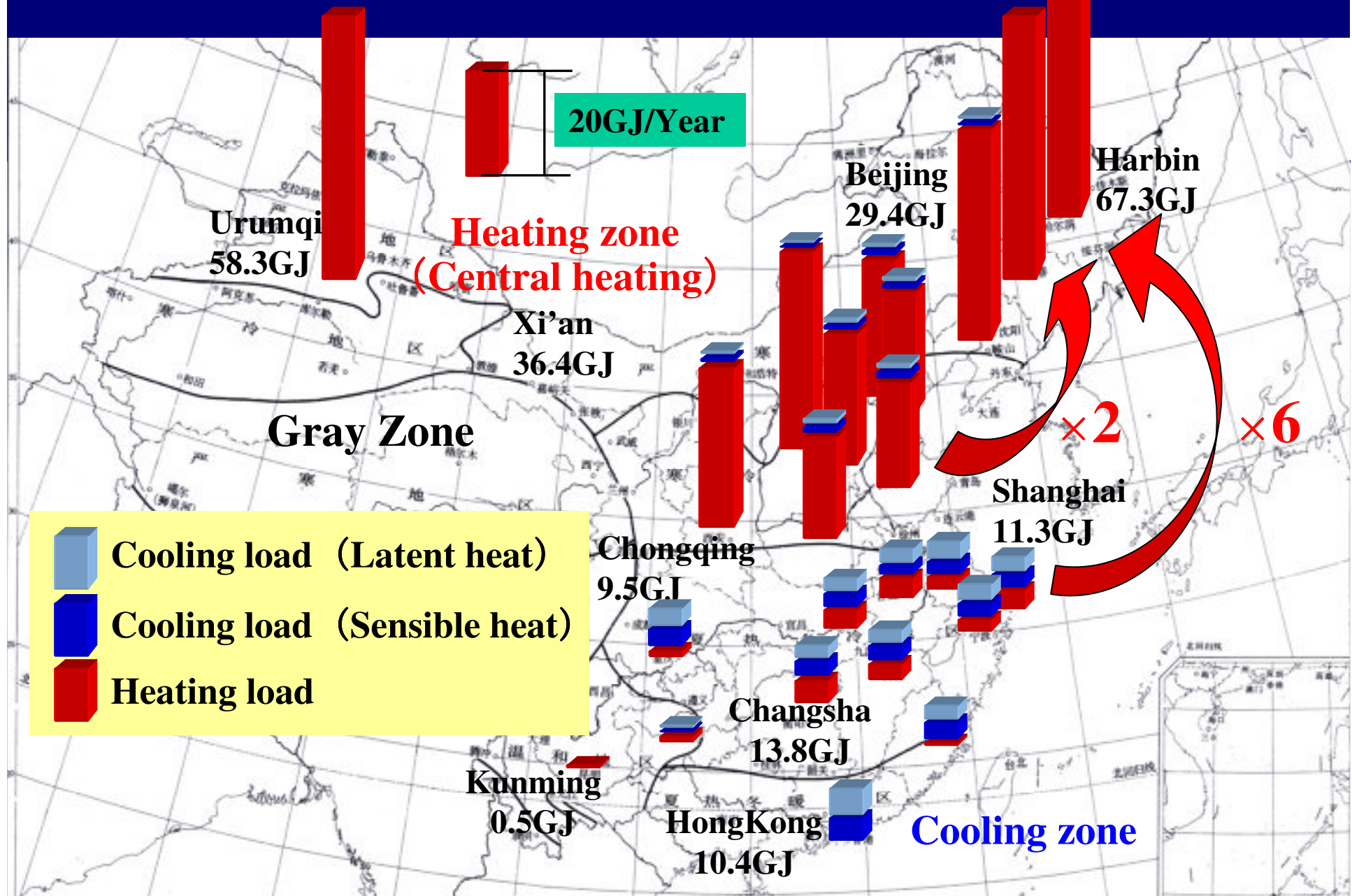
Heating : 12/5 ~ 3/5



Cooling : 7/5 ~ 9/5

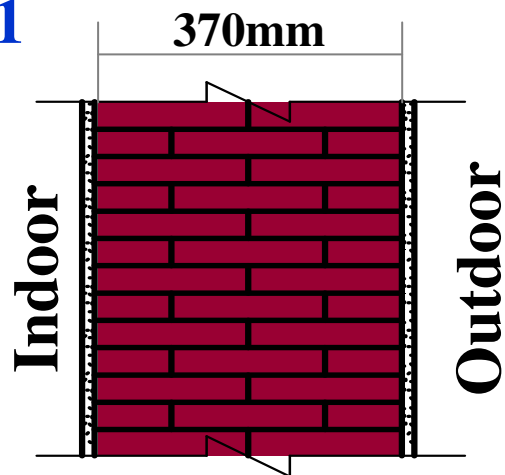


# Annual air conditioning load in main cities



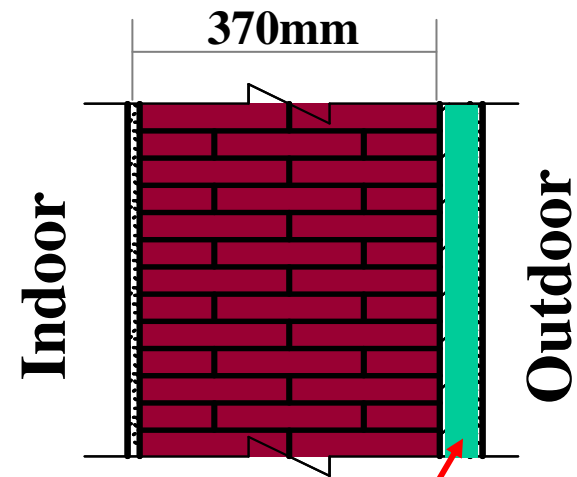
# Insulation (Beijing)

No. 1



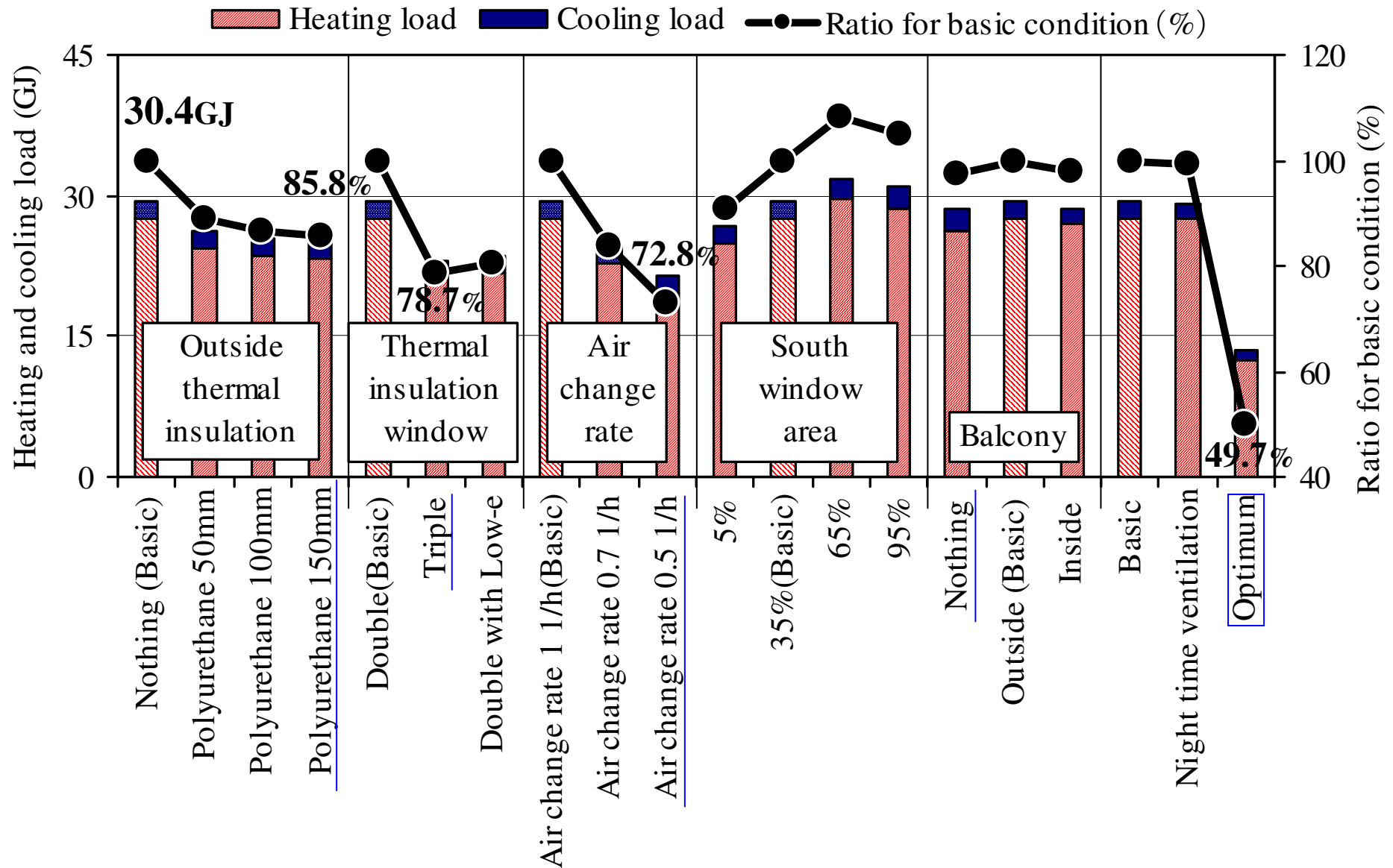
Insulation : Nothing

No. 2

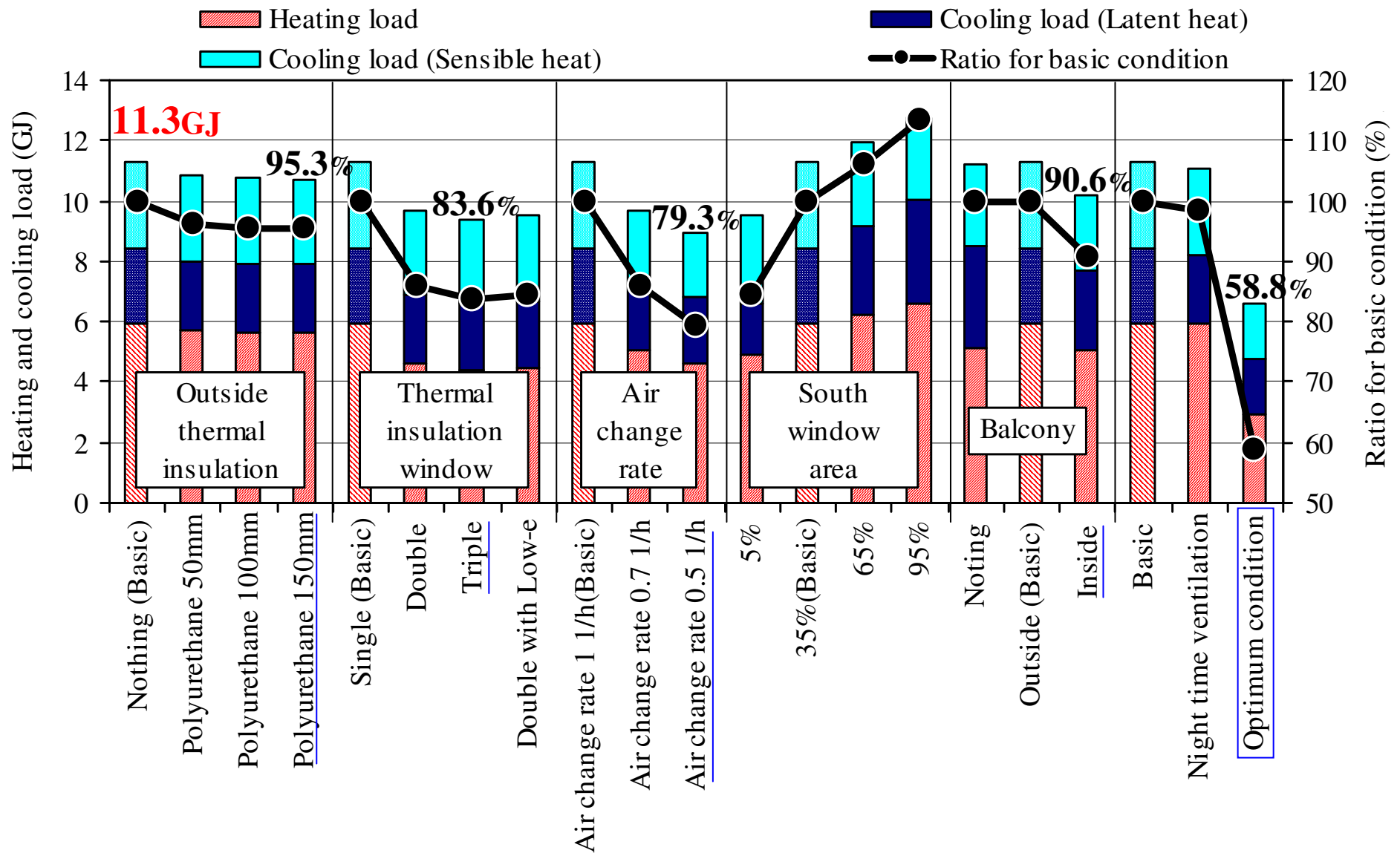


Insulation: Polyurethane foam 50mm

# Result of calculation ~Beijing~



# Result of calculation ~Shanghai~



# CONTENTS

- 1. Introduction**
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- 3. Energy use in China**
- 4. Space heating & cooling and indoor temp.**
- 5. Investigation of energy use**
- 6. Calculation of HVAC loads and energy saving**
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- In China, the level of the living standard is increasing due to the economical development. Taking into account the huge population, the effect of the increase in energy consumption is estimated extremely to be large impact on global warming.
- For the space heating, in cold climate region, thermal insulation is a fundamental strategy for energy saving. Charging system of heat supply in buildings with central heating system is very important as well.
- In mild climate region, indoor thermal comfort is not enough. It is expected that the space heating energy will increase in near future. Thermal insulation is necessary to prevent the increase of space heating energy use.
- Energy use for space cooling is rapidly increasing in all of China. Passive cooling strategy is strongly recommended.

# Proposals for promotion of building energy conservation

By The Center for Building Energy Conservation,  
Ministry of Construction P.R., China

- Establishment of standards and regulations for energy conservation
- Establishment of energy management system
- Establishment of governmental fund and economical policy for energy conservation
- Establishment of rational charging system of heat supply
- Evaluation system for energy saving technologies and products (Exp. GOBAS)

**Thank you  
for your attention!**